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VEGETATION AND FLORA OF A BIODIVERSITY HOTSPOT: PINE HILL, EL DORADO COUNTY, CALIFORNIA, USA

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ABSTRACT

Pine Hill lies near the center of a gabbrodiorite intrusion in the foothills of the Sierra Nevada mountain range in El Dorado County, CA, USA. We assembled an extensive flora, examined the distribution and associations of vascular plant taxa, and specifically focused on associations of six rare plant taxa. The influence of environmental variables on plant distribution was investigated using a stratified random plot sampling technique and applying canonical correspondence analyses. The site contained over 10% (741 plants) of the flora of the entire state of California including seven rare species. Species segregated into chaparral, oak woodland, and grassland communities. In chaparral and woodland, and on serpentine sites, over 75% of the flora was comprised of native species. The non-serpentine grassland community was dominated by exotic species (64% exotic) and contained no rare species. Shrub and tree cover were the most important biotic factors associated with plant species distribution; serpentine substrate, soil texture, elevation, and degree of disturbance were the most important abiotic factors. Five rare species were restricted to gabbro soils. Consideration of beta diversity contributed little to our understanding of vegetation patterns. Our analyses identified two types of chaparral which we termed "Xeric Seeding" and "Mesic Resprouting" to reflect the environmental conditions and the fire regeneration strategy of the vegetation. Each chaparral type contained different rare species whose regeneration strategies were concordant with chaparral regeneration type.

Key Words: CANOCO, canonical correspondence analysis, chaparral, gabbro, obligate resprouter, obligate seeder, rare plants, TWINSPAN.

Mediterranean-climate regions are known for the high diversity of their flora, collectively containing almost 20% of the world's vascular plant species while comprising an area less than 5% of the earth's surface (Cowling et al. 1996). This is due to a combination of factors acting at local to regional scales such as plant growth-form diversity and differential responses to disturbance, plant assemblages composed of habitat specialists and geographical vicariants, and spatial variation in resources due to topographic diversity and edaphic complexity (Cowling et al. 1996). In California shrublands, edaphic specialists, and patches in which varied seral stages occur following fire add to floristic richness.

Located near the center of a gabbro soil formation in the Sierran foothills 48 km east of Sacramento, CA, Pine Hill stands as one of California's remarkable "ecological islands" (Stebbins 1978), possessing a rich floristic diversity and a high concentration of rare and endangered plants (Fig. 1). The vegetation consists of open grassland, oak woodlands, and chaparral. The Pine Hill complex forms a 104 km^2 gabbrodiorite volcanic intrusion of Mesozoic origin (approximately 175 million years in age) that is surrounded by metamorphic rocks, with some granitic intrusions, and serpentine rock lands (Springer 1968). Serpentine occurs as rocky outcrops or as ridges which extend in a north-south direction. At the time this study was begun in the mid-1980s, at least six rare and endangered plant taxa were considered to exist only on Pine Hill or in the immediately surrounding areas

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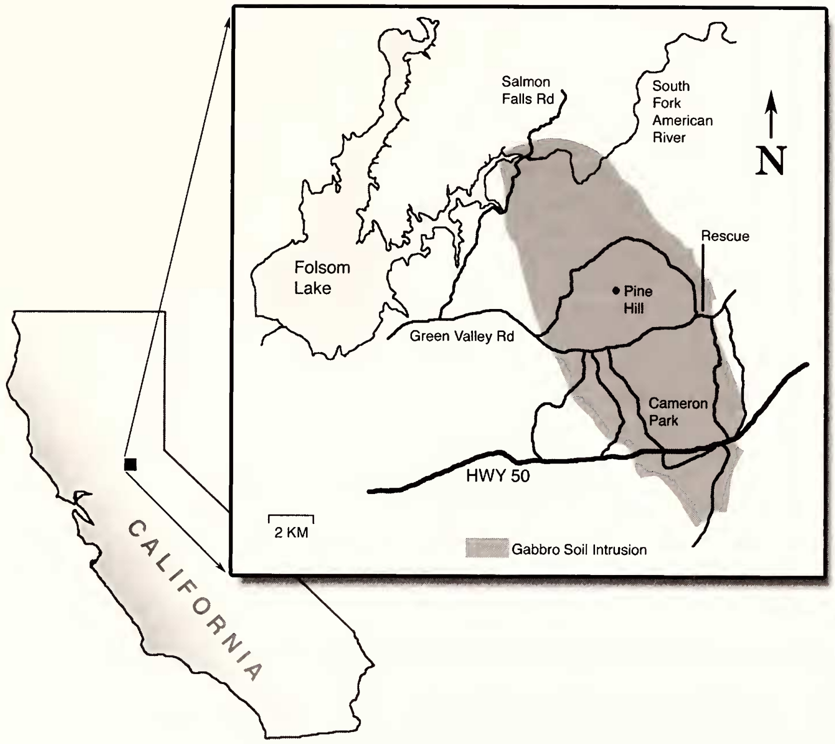

FIG. 1. Map showing the location of the gabbro soil intrusion which extends from S U.S. highway 50 to the South Fork of the American River, encompassing the towns of Cameron Park and Rescue. The center of the gabbro soil intrusion is at approximately 38°43′ north latitude and 120°59′ west longitude.

(Howard 1978; El Dorado County 2007; Baad personal obervation). Since these species were only known from gabbro soils at this locality, it appeared as if the rare plants were restricted to soils derived from gabbro parent materials.

Serpentine areas serve as an important edaphic comparison with gabbro. Serpentine is classed as an ultrabasic or ultramafic, cold intrusive rock. It is high in ferro-magnesium silicates and is especially noted for its low calcium and high magnesium levels (Whittaker et al. 1954; Kunz 1985). High concentrations of heavy metals like chromium and nickel are also generally common in this rock type. The high proportion of endemic species associated with serpentine soils has generated much study ranging from the evolutionary ecology of plant tolerance to the structure of plant communities found on serpentine (see Brady et al. 2005 for a review). The gabbro soils are considered to be edaphically similar to serpentine because of their mineral composition and because they appear to influence plant distributions. However, gabbro-derived soils in El Dorado County have a higher Ca/Mg ratio (Goldhaber et al. 2009), and lower concentrations of chromium and nickel (Morrison et al. 2009) than are characteristic of serpentine soils.

Changes in topography strongly affect the distribution of plants by providing micro-climates significant to species survival (Mason 1946; Spurr and Barnes 1973; Mooney et al. 1974; Ricklefs 1976; Hocker 1979). In California chaparral, topographically-governed moisture and insolation levels may be reflected in patterns of shrub species distribution due to their affect on germination and seedling survival (Meetemeyer et al. 2001); hot, exposed sites tend to contain species with seeds cued to germinate after fire and seedlings that have high tolerance to drought, while sheltered slopes contain resprouting species with seeds that depend on cool, moist conditions for germination and subsequent growth. The topography of the Pine Hill complex is rich in its variety of slope and aspect varying from small flat valleys with gently rolling hills to steep river canyons and prominent peaks (though only a few of these extend above 600 meters in elevation) and thus, topography may play an important role in the diversity of the area's flora and in the distribution of the rare plants on the Pine Hill complex. The overall climate is relatively consistent over the entire region and is characteristic of California's Mediterranean climate with warm, dry summers and cool, wet winters. The average annual precipitation, recorded nearby at Folsom Lake, is 65 cm and occurs mostly in the form of rain in the winter months (USBR 1981).

In addition to being noted for its unique plant life, the Pine Hill region of El Dorado County was considered a desirable area for residential development. Easy freeway access from the city of Sacramento encouraged rapid and extensive development with much of the land being cleared for commercial and residential uses. By 1996 several plant species were federally listed under the U.S. Endangered Species Act as endangered, threatened, or of special concern (U.S. Fish and Wildlife Service 1996); others were listed as rare by the California Native Plant Society (Table 1) due to urbanization, habitat fragmentation, road construction, herbicide spraying, change in fire frequency, off-road vehicle use, unauthorized dumping, overgrazing, mining, and competition from invasive alien vegetation. Preserves to protect the rare species have been established throughout the Pine Hill area (for a brief history see Brink 2010). Of the 2,024 ha (5,001 acres) that are within the target recovery area's boundaries, at least 325 ha (803 acres) have been lost due to development while 1,309 ha (3,234 acres) within the recovery boundary are protected within formal preserves (DeLacy, American River Conservancy; Hinshaw, Bureau of Land Management, personal communications). The federal listing of five species has been effective in providing protection for large areas of a unique chaparral ("Northern Gabbroic", Holland 1986) and has provided collateral protection for seven rare, but unlisted plant species (Pavlik 2003).

Our goals in this study were to compile a flora for the Pine Hill region, classify the plant communities using Two-way Indicator Species Analysis (TWINSPAN), and to investigate the distributions of plant communities in relation to environmental factors using canonical correspondence analysis and permutation tests in CANOCO. We considered both biotic factors (vegetation cover, cover by exotic, native or rare species, vegetation height, etc.) and abiotic factors (slope, aspect, rock type, soil chemistry, disturbance, etc.). Further, we wished to specifically determine the community and plant associations, and environmental correlates of the rare and endangered plants.

Materials and Methods

Study Area

In order to evaluate the influence of gabbro soil on plant distribution, we extended the boundaries of the study area beyond the immediate Pine Hill area to include other soil types. We located 148 plots between the elevations of 120 and 670 meters and approximately between north latitude 38°38′ and 38°57′. Pine Hill, at an elevation of 628 meters (USGS 1973) is located near the center of the study area (at approximately 38°43′ north latitude and 120°59′ west longitude). Approximately 60% of the plots were on gabbro soil.

The Floristic Study of Pine Hill and Vicinity

Plant identification and taxonomy used in this work conform to the nomenclature of Hickman (1993). Existing specimens from the California State University, Sacramento herbarium (CSUSH) were used to confirm identifications. Plant specimens were collected between 1981 and 1985 during all seasons and placed in CSUSH. Whenever rare plant species were observed during explorations of the study area, their locations were mapped onto USGS 7.5 min quad maps and any unusual circumstances noted. Map locations were converted to UTM coordinates in 2008. Selected sites previously recorded by others were visited to confirm the presence of rare species, but the primary emphasis of this study was to find new rare plant locations. New locations were reported to the California Natural Diversity Database (2008).

Stratified Random Plot Study

Aerial photographs (USGS 1979) were used to map the overall distribution of the basic vegetation types and the fraction covered by each vegetation type was estimated using graph paper. Ground truthing verified photo interpretation. The vegetation map served as a guide to locate the stratified, random sample plots as well as a means of calculating coverage area for vegetation types as they occurred upon the Pine Hill gabbro formation in 1979. From these calculations, chaparral was the most widespread vegetation with a cover of 44.8%, followed by woodland at 28.3% and grassland at 26.9%.

The number of sample plots per vegetation type was assigned in proportion to the relative aerial coverage of each type. Since a comparison was to be made between vegetation on gabbro soil and that on non-gabbro soil, the number of plots "on" and "off" the gabbro needed to be relatively consistent within the percentages of each vegetation type found on the gabbro formation. Approximately 40% of the plots assigned to each vegetation category were located on non-gabbro soil.

Appropriate plot sizes were determined experimentally using a nested plot technique and standard species area curve calculations for greater than 90% coverage (Mueller-Dombois and Ellenberg 1974). This technique to determine plot size was used to insure that the samples taken from each vegetation type would be comparable in species diversity. The actual plot sizes used for each vegetation category were as follows: for chaparral, 42 m^2 (3.25 m × 13 m); for

TABLE 1. THE EIGHT RARE VASCULAR TAXA OF THE PINE HILL GABBRO COMPLEX, THEIR LISTING STATUS, PERCENT OF PLOTS WHERE FOUND, THE SOIL TYPES WHERE THEY GREW, AND THEIR FIRE REGENERATION STRATEGIES (F = FACULTATIVE SEEDER/RESPROUTER; R = OBLIGATE RESPROUTER; S = OBLIGATE SEEDER). [1] Known from other soil types outside the Pine Hill area. [2] Not found during this study, but reported to be present (California Department of Fish and Game, 1978; Aparicio 1978); the legitimacy of *H. suffrutescens* as a distinct taxon is controversial.

Taxon	Federal status	Common name	Percent of plots where found	Soil type	Fire regeneration strategy
Calystegia stebbinsii Brummitt	endangered	Stebbins' morning-glory	0.7	gabbro[1]	S (possibly F)
Ceanothus roderickii W. Knight	endangered	Pine Hill ceanothus	6.5	gabbro	S
Chlorogalum grandiflorum Hoover	not listed	Red Hills soaproot	10.1	gabbro[1]	R
Fremontodendron californicum (Torr.) Coville ssp. *decumbens* (R. Lloyd) Munz	endangered	Pine Hill flannelbush	1.4	gabbro	F
Galium californicum Hook. & Arn. ssp. *sierrae* Dempster & Stebbins	endangered	El Dorado bedstraw	5.0	gabbro	R
Helianthemum suffrutescens Schreib.	not listed	Bisbee Peak rush-rose	0.0	not found[2]	S?
Packera layneae (Greene) W.A. Weber & A. Löve	threatened	Layne's butterweed	4.3	gabbro, serp, meta	R
Wyethia reticulata Greene	species of concern	El Dorado County mule ears	7.2	gabbro	R

woodland, 100 m^2 (5 m × 20 m); and for grassland, 25 m^2 (2.5 m × 10 m). Rectangular plots were used as they yield more representative data than plots of other shapes (Mueller-Dombois and Ellenberg 1974).

A total of 148 sample plots was established throughout the study area between July 1984 to February 1985; vegetation and floristic data were taken during spring and summer 1985. At the end of the study period, only 139 of these plots remained. Nine plots were lost due to road building or development. Specific plot locations were assigned using a stratified random sampling method. This method allowed the sampling of specific areas, in between anthropogenically disturbed places, while retaining the advantages of random sampling. A random numbers chart was used to determine direction of travel, distance taken to reach a specific point, and to determine plot orientation. Specific study areas were chosen on the basis of observed environmental variation in the interest of including significant gradients for data analysis.

Environmental data recorded at each plot location were slope, aspect, elevation, soil texture and rock types, soil calcium and magnesium, disturbance, available water, and vegetation cover. Specific slope and aspect measurements were determined using a pocket transit. To reflect the sun exposure, aspects were assigned numerical values on a gradient from 1 to 8 with 1 (SW) indicating maximum exposure, and 8 (NE) indicating minimum (SW = 1, S = 2, W = 3, SE = 4, NW = 5, E = 6, N = 7, NE = 8). Surface estimates of soil texture were made by rating the proportions of rock to clay and a numerical scale was constructed to indicate a gradient from extreme rocky outcrop (value of 1) to soils of mostly fine silt and clay (value of 4). Elevations were estimated at each plot location using topographic maps. Geology substrate maps and field identification of the rocks within each plot were used to determine the parent material of the soil. The U.S. Department of Agriculture's soil surveys (Rogers 1974; USDA 1980) were used to check field observations on rock and soil parameters. The levels of calcium and magnesium in the soil were determined using the Model 14855 Soil Calcium and Magnesium Test Kit available from Hach Co., Loveland, Colorado.

Note was taken of any evidence of disturbance due either to human activities, such as grazing or clearing, or natural events, such as fire. Disturbances were recorded with regard to (1) the extent to which they affected the plants within the plot and (2) recentness of their occurrence. These two factors were rated. Ratings on recentness (time) were scaled with end points from 1 (long ago - little or no evidence remaining) to 7 (recent - within the last 2 yr). Extent of the disturbance was rated from 1 (disturbance area and type minimal) to 4 (major disturbance, all plants destroyed). The two factors were multiplied by each other to obtain a value for each plot.

Observable surface water was estimated using a scale as follows: 1 = always dry, no water nearby; 3 = near seasonal water supply, mostly dry; 5 = near a permanent source of water, stream or lake; and 7 = water within plot most of the year.

Differences in cover were estimated on the basis of the total amount of plant cover present in the three structural levels of trees, shrubs and groundcover (herbs and grasses). The method used for estimating cover was a modification of methods described in the literature (Daubenmire 1974; Mueller-Dombois and Ellenberg 1974). The cover values used in this study were: 8 = 95.1 to 100% cover; 7 = 75.1 to 95% cover; 6 = 50.1 to 75% cover; 5 = 25.1 to 50% cover; 4 = 10.1 to 25% cover; 3 = 5.1 to 10% cover; 2 = 1.0 to 5% cover; 1 = <1% cover.

In addition to the measurable data gathered for each plot, other factors were included. "Latitude" values for each plot were assigned as the distance in miles north from the southernmost plot location in the study. We noted the number of rare species found within each sample plot. The soil survey for El Dorado Co. (Rogers 1974) rates the suitability of various sites for general farming using the Storie Index rating which takes into account soil profile, texture, slope and other conditions such as drainage. High ratings imply few restrictions to agricultural plants while lower ratings indicate increased limitations to farming. Since the Storie Index is a calculation indicating a soil and plant growth relationship, it was included in the analysis. Depth to bedrock was also noted from the soil survey (Rogers 1974). Table 2 lists the physical, descriptive, and vegetation variables considered in the study.

The Shannon diversity index (H′) was computed for each sample and used as a measure of alpha diversity or the species diversity within samples (Krebs 1999). The Shannon H evenness index (evenness = H′/log(N)) was used as a measure of how equitable and homogeneous species diversity was among samples. Equitability assumes a value between 0 and 1 with 1 being complete evenness. Diversity and evenness were compared for each rock formation and vegetation category.

Data Analyses

Two-way Indicator Species Analysis (TWINSPAN) (Hill 1979) is a classification program which organizes plot samples into community groups on the basis of species composition (identity and cover) using a divisive clustering algorithm. Plots with similar associations are grouped together by TWINSPAN and the program organizes species on the basis of their affinities for these groups into plant associations. We analyzed our data using a FORTRAN version of TWINSPAN and that ran on a main-frame computer (Alcor) at the University of California, Davis in 1985.

Canonical Correspondence Analysis (CCA here after) is a constrained ordination technique that finds axes of the greatest variability in community composition for a set of samples (ter Braak 1986; ter Braak and Šmilauer 2002). Community composition is defined by the number, identity, and abundance of species. CCA uses weighted averaging to search for the best explanatory variables where species abundances are the weights. Assuming the species have unimodal responses for the explanatory variables, weighted averaging is the simplest way to find the species optima (i.e., species scores) for those variables. A preliminary detrended correspondence analysis (DCA) by segments was used to assess segment length of gradients using CANOCO for Windows (Hájek et al. 2002; ter Braak and Šmilauer 2002). The DCA showed that gradients were 5.20 standard deviations long and thus were conducive to unimodal methods such as CCA (Leps and Smilauer 2003). As well, data diagnostics were performed to access the assumption of unimodal response of the species data to the explanatory variables.

The CCA program CANOCO (Leps and Smilauer 2003) was used to arrange all plant species along the measured environmental gradients. The quantitative and nominal environmental variables we used are listed in Table 2. Species cover class values were backtransformed to percent cover using the midpoint value of the cover class and then were log transformed (plus a constant of one) because of the many zero values in order to remedy the positive skew in frequency distribution of species cover. Species with low overall cover were downweighted in the analysis to reduce the undue influence of these rarer species on the CCA (Fig. 2). This influence occurred because many of the low cover species co-occurred in samples with a few more common species (ter Braak and Šmilauer 2002).

All measured and computed (e.g., Shannon H) environmental variables were subjected to Monte Carlo permutation tests in CCA to provide p-values to assess the marginal significance of each variable individually. The conditional effect of each variable was assessed as each was added to a model during forward selection to explain total variation in community structure. During this process, multicolinearity was detected among several of the variables causing a slight arch effect in the CCA biplots. A correlation matrix was generated and sorted using the CORR procedure in SAS software for all environmental variables in order to identify redundant environmental variables (SAS Institute Inc. 2004). Any pairwise correlation exceeding 0.60 resulted in the selection of the most objective and ecologically

TABLE 2. VARIABLES SELECTED BY FORWARD SELECTION AND TESTED BY MONTE CARLO PERMUTATION. The variable codes were used in the CCA biplots. The marginal effect (λ_1) for each variable is a measure of the variance each explains when that particular variable is the only environmental variable used. The variables were categorized as abiotic or biotic for variance partitioning (see text for details). [1] Designated as nominal variables, all others are quantitative. [2] Variables not selected by MonteCarlo simulation.

Variables	Code	λ_1	Definition or how measured:
ABIOTIC			
Aspect	Aspt	0.13	measured with a Brunton pocket transit
Bedrock	Bdrk	0.11	depth to bedrock
Ca/Mg[2]	Ca/Mg		chemically tested soil values in situ
Disturbance	Dist	0.25	numerical assessment of degree and recency of disturbance
Elevation	Elev	0.13	estimated from 7.5 min. topographic maps
Latitude	Lati	0.11	distance north from southernmost plot in miles
Gabbro[1]	Gabb	0.12	nominal variable designates gabbro rock formation sites
Serpentine[1]	Serp	0.17	nominal variable designates serpentine rock formation sites
Granite[1]	Gran	0.10	nominal variable designates granite rock formation sites
Metamorphic[1]	Meta	0.09	nominal variable designates metamorphic rock formation sites
Slope	Slpe	0.17	measured with a Brunton pocket transit
Soil Ca	CA	0.09	chemically tested soil Ca in situ
Storie index	Stor	0.30	index of agricultural suitability
Surface	Text	0.20	soil texture field estimate
Water	H20	0.17	availability of surface water in or near plot
BIOTIC			
Cover	Covr	0.19	percent of plot area covered by all plants estimated visually
Diversity	Dive	0.28	#families/#species
Evenness	Even	0.16	calculated as H′/ln(Exot + NatS)
Groundcover	GrCov	0.31	percent of plot covered by forbs estimated visually
Height[2]	Height		estimate of overall plant height
Exotic species	Exot	0.40	number of introduced species
Native species	NatS	0.38	number of native species
Tree cover	TrCov	0.46	percent of plot covered by trees estimated visually
Rare species	Rare	0.20	number of rare species
Shade[2]	Shade		estimate of coverage at 5 dm height
Shannon H′	Shan	0.23	calculated as H′ (Krebs 1999)
Shrub cover	ShCov	0.58	percent of plot covered by shrubs estimated visually
Unique species	Uniq	0.13	species found in only a single plot
Chaparral[1]	Chap	0.48	nominal variable designates chaparral sites
Grasslands[1]	Gras	0.51	nominal variable designates grassland sites
Woodland[1]	Wood	0.45	nominal variable designates woodland sites

meaningful variable of the pair, and elimination of the other correlated variable with the exception of two pairs of important explanatory variables that had correlations exceeding 0.8: ground cover was correlated with grasslands, a nominal site variable, and tree cover was correlated with "Woodland", also a nominal site variable (both correlations >0.80). The remaining explanatory variables were subjected to another forward selection and Monte Carlo permutation to remove those variables that did not explain significant portions of the overall variance singly without the influence of any other variable. These variables were highly unlikely to contribute to an overall explanatory model of species variability among the sites. Multicollinearity was not detected in subsequent CANOCO analyses with the final set of environmental variables. In a final CCA analysis, significant variables were identified and their conditional P-values estimated by Monte Carlo permuation.

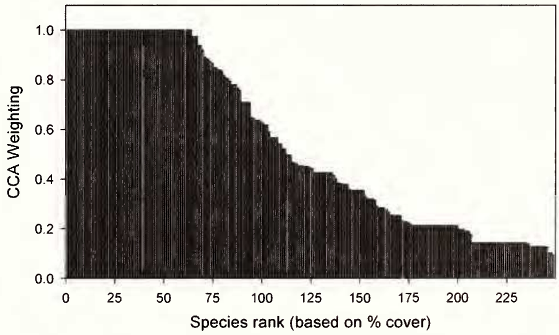

FIG. 2. Down-weighting scheme used for CCA, where a weight of 1 means the species carries its original influence on the ordination and lower weights reduce less frequently occurring species undue influence on the analysis (see ter Braak and Smilauer 2002). Species were arranged on the X-axis from most frequent on the left to least frequent on the right.

The final CCA diagram of species scores with biplot scaling, and biplot scores of the quantitative variables and centroid scores of the nominal variables were interpreted for community structure (Leps and Smilauer 2003). Multiple CCAs were run to partition the total variance into separate 'biotic' (B) factors (plant cover, species numbers, etc.) and 'abiotic' (A) factors (soil calcium, soil type, water availability, etc.; Table 2) (Legendre 2007). We did this to see how much of community composition was determined by site characteristics such as resource availability (A), by plant-plant interactions (B) and how much was shared between these two categories (C). We estimated the A, B, and C fractions using five partial constrained ordinations. From these five analyses we were able to decompose the total variance in the species data set into abiotic, biotic, and shared sources of explained variance.

Variance decomposition was performed where the two spatially explicit variables, longitude and latitude from UTM data were partitioned from the remaining environmental variables (Legendre et al. 2005). This decomposition was done to assess for differences in spatial (beta) diversity.

Results

Floristic Content of the Study Area

Over one thousand plant specimens were collected on numerous trips to the region. The final list of plants from the entire study area, on and off gabbro, is a composite of species identified by various individuals working in the area (Appendix 1). The list includes 741 distinct taxa (including 91 subspecies or variaties, 8 species of ferns, and 3 species of mosses) in 376 genera, representing 91 families. The families with the most taxa were Asteraceae (108 species and subspecies), Poaceae (71), and Fabaceae (58).

During the plot study, 342 species and varieties were identified within the plot borders (Appendix 1). The taxa found in the plots belonged to 216 genera that occurred within 66 vascular plant families; 267 (approximately 78%) were California natives. The mean number of plants found in each plot was 24, and the mean percentage of California native taxa occurring throughout all plots was 64.1% (Table 3). We found 219 species in "Woodland" areas, of which 76% were native species. One "Woodland" plot, 100 m^2 in size, contained 61 species of plants. The chaparral contained 190 species, of which 76% were native. Within the "Woodland" areas, serpentine and gabbro had the highest levels of natives at 96% and 81%, respectively. On the other hand, only 36% of the 149 species found in grassland were native species according to Hickman (1993). Serpentine grasslands, however, had a greater proportion of native species (66%) than non-serpentine grasslands. The 100 most frequently encountered species in the plots, which included rare species *Calystegia stebbinsii* Brummitt, *Ceanothus roderickii* W. Knight, *Chlorogalum grandiflorum* Hoover, and *Wyethia reticulata* Greene along with the three other listed species (*Fremontodendron californicum* (Torr.) Coville ssp. *decumbens* (R. Lloyd) Munz, *Galium californicum* Hook. & Arn. ssp. *sierrae* Dempster & Stebbins, and *Packera layneae* (Greene) W.A. Weber and A. Löve) are listed in Table 4 with their 4-letter species codes.

The low-growing native herb *Galium porrigens* Dempster was the most common species found (Table 4) and grew in over 80% of the "Woodland" and shrub plots, but was never found in grasslands (Table 5) while the exotic grasses *Aira caryophyllea* L. and *Bromus madritensis* L. occurred in about 80 plots and were found in all three community types (Tables 4 and 5). The shrubs with the highest frequency and cover were native species *Arctostaphylos viscida* Parry and

Table 3. Numerical Distributions of the Study Area's Flora as Sampled by the Stratified Random Plot Study. Number in parentheses is the number of plots in the category.

Categories	Values
A. Overall taxa distribution	Number of taxa
All plots (139)	342
Gabbro plots (80)	253
Serpentine plots (17)	141
Metamorphic and granite plots (42)	225
Grassland plots (38)	149
Woodland plots (38)	219
Chaparral plots (63)	190
B. Gabbro soils only	Number of taxa
Grassland gabbro plots (22)	85
Woodland gabbro plots (22)	145
Chaparral gabbro plots (36)	150
C. Species densities	Mean taxa per plot
All plots	24
Chaparral plots	21
Grassland plots	20
Woodland plots	35
Gabbro plots	26
Metamorphic plots	23
Granite plots	20
Serpentine plots	24
D. Percent native taxa	Mean percent per plot
All plots	64.1
Chaparral plots	75.5
Grassland plots	36.1
Woodland plots	76.3
Gabbro plots	64.0
Metamorphic plots	62.5
Granite plots	37.2
Serpentine plots	76.4

Adenostoma fasciculatum Hook. & Arn. (Table 4) which were found in ca. 75% of the "tall, closed-canopy chaparral" and "Woodland" plots, and on all soil types, but were never found in grassland (Table 5). The tree with the highest frequency and cover was the native oak *Quercus wislizenii* A. DC., a dominant species of "Woodland". It was frequently found in shrub plots and was also found in a few grassland plots.

Classification

Based on their floristic composition, the 138 plots were classified by TWINSPAN into three main communities: "Woodland", Shrub, and "Grassland". Table 5 lists the classification of the 100 most common species although the analysis was run using all 347 species and varieties. "Woodland"-type communities were generally found on non-serpentine soils. Within the "Woodland" community types, TWINSPAN further delimited "Blue Oak Savanna", a community dominated by *Quercus douglasii* Hook. & Arn. and mostly-native forbs; "Woodland", a native-species rich community characterized by high diversity of trees, including the oaks *Quercus wislizenii* and *Q. kelloggii* Newb. and Ponderosa pine (*Pinus ponderosa* C. Lawson), vines including native honeysuckles (*Lonicera* spp.) and abundant poison-oak (*Toxicodendron diversiloba* (Torr. & A. Gray) Greene), and native grasses, forbs, and bulbs; and a "Chaparral-Woodland" transitional community type that was characterized by the shrubs toyon (*Heteromeles arbutifolia* (Lindl.) M. Roem.), redbud (*Cercis occidentalis* Torr.) and coffee berry (*Rhamnus tomentella* Benth. ssp. *crassifolia* (Jeps.) J. O. Sawyer), and Foothill pine (*Pinus sabiniana* Douglas) – species which also grew on serpentine soils. *Wyethia reticulata*, a species of concern, was included in the main "Woodland" group, near the "Chaparral-Woodland" transition group.

The Shrub-dominated communities were found on all soil types including serpentine. Shrub communities were divided into "Short-Chaparral" dominated by native low-growing shrubs, forbs, and grasses - a high proportion of which were found growing on serpentine soils; "Tall, Closed-Canopy Chaparral" dominated by the shrubs *Adenostoma fasciculatum* Hook. & Arn. (chamise), *Arctostaphylos viscida* Parry (manzanita), the low growing *Salvia sonomensis* Greene, and the rare species *Ceanothus roderickii* and *Chlorogalum grandiflorum*.; and openings in chaparral, "Open Chaparral, where the exotic grasses *Vulpia myuros* (L.) C. C. Gmel. and *Aira caryophyllea* L. were commonly found. Both of these grasses had high occurrence in all three main community types.

In the "Grassland" community type, 80% of the most frequently encountered species were exotic. "Grasslands" were dominated by exotic annual grasses, especially the brome grasses (*Bromus spp.*), oats (*Avena spp.*), and exotic forbs, especially *Hypochoeris* spp. and *Erodium* spp.

Results of CCA of the Pine Hill Vegetation

Shrub and Tree Cover (quantitative variables) and community classifications (nominal variables) explained the highest amount of variance in the CCA when we evaluated the marginal significance of each variable individually (Table 2). Serpentine was the only soil type that explained much variation (Table 2). The conditional effect of each variable was assessed as each was added to a model during forward selection to explain total variation in community structure (Table 6). The final model that resulted from forward selection found the Shrub and Tree cover variables to have the highest conditional effects ($\lambda_A = 0.58$ and 0.45, respectively) and thus were the first variables to be included in the multivariate model (Table 6). The Serpentine variable was the only abiotic variable (and only rock formation) found to have a moderately high conditional ($\lambda_A = 0.15$) effect relative to the biotic variables, followed by elevation, surface texture, and degree of disturbance ($\lambda_A = 0.09, 0.08, 0.08$, respectively).

The first two axis of the CCA biplot depicted three main clusters around variables that generally describe communities dominated by grassland, chaparral, and woodland species (Fig. 3). There was a smaller cluster of species scores situated between the "Woodland" and chaparral clusters. The tree, shrub and exotic species variables had the longest arrows in the CCA biplot, and were therefore most strongly related to community structure. The first CCA axis (x-axis) was dominated by information contained in exotic species numbers to the right ($r_{ExoSp\text{-}CCA1} = 0.73$) and shrub cover to the left ($r_{ShCov\text{-}CCA1} = -0.91$) (Fig. 3), and separated the open grasslands and blue oak and valley oak savannas from shrub and tree dominated woodlands and shrublands. The shrub species were most often native shrub species ($r_{ShCov\text{-}NatS} = 0.74$). The second CCA axis (y-axis) was dominated by tree cover ($r_{TrCov\text{-}CCA2} = -0.91$) and "Woodland" sites ($r_{Wood\text{-}CCA2} = -0.89$) in one direction, and chaparral sites ($r_{Chap\text{-}CCA2} = 0.63$) in the other direction, and separated the chaparral from "Woodland".

The proximity of species in the CCA biplot was indicative of their co-occurrence in the samples and aggregations of species were sorted into communities (Table 7). The species with the highest cover observed in this study, *Adenostoma fasciculatum* (ADFA) is most closely associated

TABLE 4. STUDY CHARACTERISTICS OF THE ONE HUNDRED MOST FREQUENT TAXA IN THE STUDY, WHICH INCLUDED RARE TAXA CERO, CHGR, AND WYRE, PLUS FOUR OF THE RARE TAXA, CAST, FRCA, GACA, AND PALA. Taxa are listed by their four-letter codes. Rare species are denoted with an asterisk.

Taxon code	Taxon	Family	Number of plots	Average cover (%)
ACMI	*Achillea millefolium* L.	Asteraceae		
ADFA	*Adenostoma fasciculatum* Hook. & Arn.	Rosaceae	60	16.8
AECA	*Aesculus californica* (Spach) Nutt.	Hippocastanaceae		
AETR	*Aegilops triuncialis* L.	Poaceae		
AICA	*Aira caryophyllea* L.	Poaceae	80	1.5
ARVI	*Arctostaphylos viscida* Parry	Ericaceae	72	13.6
AVBA	*Avena barbata* Link..	Poaceae	43	2.4
AVFA	*Avena fatua* L.	Poaceae		
BAPI	*Baccharis pilularis* DC. ssp. *consanguinea* (DC.) C.B. Wolf	Asteraceae		
BRDI	*Bromus diandrus* Roth	Poaceae	37	5.1
BRDS	*Brachypodium distachyon* (L.) P. Beauv.	Poaceae		
BREL	*Brodiaea elegans* Hoover	Liliaceae		
BRHO	*Bromus hordeaceus* L.	Poaceae	56	8.7
BRLA	*Bromus laevipes* Shear	Poaceae		
BRMA	*Bromus madritensis* L.	Poaceae	79	1.9
BRMI	*Briza minor* L.	Poaceae		
BRST	*Bromus sterilis* L.	Poaceae		
CAAL	*Briza minor* L.	Liliaceae	51	0.3
CABR	*Carex brainerdii* Mack.	Cyperaceae		
CAOL	*Cardamine oligosperma* Torr. & A.Gray	Brassicaceae		
*CAST	*Calystegia stebbinsii* Brummit	Convolvulaceae		
CECU	*Ceanothus cuneatus* (Hook.) Nutt.	Rhamnaceae		
CEGL	*Cerastium glomeratum* Thuill.	Caryophyllaceae		
CELE	*Ceanothus lemmonii* Parry	Rhamnaceae		
CEOC	*Cercis occidentalis* Torr.	Fabaceae		
CEPA	*Ceanothus palmeri* Trel.	Rhamnaceae		
*CERO	*Cenothus roderickii* W. Knight	Rhamnaceae		
*CHGR	*Chlorogalum grandiflorum* Hoover	Liliaceae		
CHPO	*Chlorogalum pomeridianum* (DC.) Kunth	Liliaceae		
CLLA	*Clematis lasiantha* Nutt.	Ranunculaceae		
CLPE	*Claytonia perfoliata* Donn ex Willd.	Portulacaceae		
CYEC	*Cynosurus echinatus* L.	Poaceae		
DICA	*Dichelostemma capitatum* Alph. Wood	Liliaceae		
DIMU	*Dichelostemma multilflorum* (Benth.) A. A. Heller	Liliaceae		
DIVO	*Dichelostemma volubile* (Kellogg) A. A.Heller	Liliaceae		
ELGL	*Elymus glaucus* Buckley ssp. *jepsonii* (Burtt Davey) Gould	Poaceae		
ELMU	*Elymus multisetus* (J.G. Smith) Burtt Davy	Poaceae		
ERCA	*Eriodictyon californicum* (Hook. & Arn.) Torr.	Hydrophyllaceae		
ERCI	*Erodium cicutarium* (L.) L'Her. ex Aiton	Geraniaceae		
ERLA	*Eriophyllum lanatum* (Pursh) Forbes var. *grandiflorum* (A. Gray) Jeps.	Asteraceae		
ERBR	*Erodium brachycarpum* (Godr.) Thell.	Geraniaceae		
FIGA	*Filago californica* Nutt.	Asteraceae		
*FRCA	*Fremontodendron californicum* (Torr. Coville) ssp. *decumbens* (R. Lloyd) Munz	Sterculiaceae		
GAAP	*Galium aparine* L.	Rubiaceae	48	1.2
*GACA	*Galium californicum* Hook. & Arn. ssp. *sierrae* Dempster & Stebbins	Rubiaceae		
GADI	*Galium divaricatum* Pourr. ex Lam.	Rubiaceae		
GAPO	*Galium porrigens* Dempster	Rubiaceae	82	0.8
GAVE	*Gastridium ventricosum* (Gouan) Schinz & Thell.	Poaceae		
GEDI	*Geranium dissectum* L.	Geraniaceae		
GEMO	*Geranium molle* L.	Geraniaceae		
HEAR	*Heteromeles arbutifolia* (Lindl.) M. Roem.	Rosaceae	66	6.4
HEMI	*Hesperolinon micranthum* (A. Gray) Small	Linaceae		
HOMU	*Hordeum murinum* L. ssp. *leporinum* (Link) Arcang.	Poaceae		
HOVI	*Holocarpha virgata* (A. Gray) D.D. Keck	Asteraceae		
HYGL	*Hypochaeris glabra* L.	Asteraceae	41	0.5
HYRA	*Hypochaeris radicata* L.	Asteraceae		

TABLE 4. CONTINUED.

Taxon code	Taxon	Family	Number of plots	Average cover (%)
IRMA	*Iris macrosiphon* Torr.	Iridaceae		
LASU	*Lathyrus sulphureus A.* Gray	Fabaceae		
LECA	*Lepechinia calycina* (Benth.) Epling ex Munz	Lamiaceae		
LOHI	*Lonicera hispidula* (Lindl.) Dougl. ex Torr. & A. Gray var. *vacillans* A. Gray	Caprifoliaceae		
LOIN	*Lonicera interrupta* Benth.	Caprifoliaceae		
LOMI	*Lotus micranthus* Benth.	Fabaceae		
LOMU	*Lolium multiflorum* L.	Poaceae		
LUBI	*Lupinus bicolor* Lindl.	Fabaceae		
LUCO	*Luzula comosa* E. Mey.	Juncaceae		
MAEX	*Madia exigua* (Sm.) A. Gray	Asteraceae		
MAGR	*Madia gracilis* (Sm.) D. D. Keck	Asteraceae		
MECA	*Melica californica* Scribn.	Poaceae		
METO	*Melica torreyana* Scribn.	Poaceae		
MICA	*Micropus californicus* Fisch. & C.A. Mey.	Asteraceae		
MOVI	*Monardella villosa* Benth.ssp. *villosa*	Lamiaceae		
*PALA	*Packera layneae* (Greene) W.A. Weber & A. Löve	Asteraceae		
PETR	*Pentagramma triangularis* (Kaulf.) Yatsk., Windham & e. Wollenw.	Pteridaceae		
PIPO	*Pinus ponderosa* C. Lawson	Pinaceae		
PISA	*Pinus sabiniana* Douglas	Pinaceae		
PLER	*Plantago erecta* Morris	Plantaginaceae		
POCO	*Polygala cornuta* Kellogg	Polygalaceae		
QUCH	*Quercus chrysolepis* Leibm.	Fagaceae		
QUDM	*Quercus dumosa* Nutt.	Fagaceae		
QUDO	*Quercus douglasii* Hook. & Arn.	Fagaceae		
QUKE	*Quercus kelloggii* Newb.	Fagaceae		
QUWI	*Quercus wislizenii* A. DC.	Fagaceae	40	9.9
RAOC	*Ranunculus occidentalis* Nutt. var. *eisenii* (Kellogg) A. Gray	Ranunculaceae		
RHIL	*Rhamnus ilicifolia* Kellogg	Rhamnaceae	38	0.7
RHTO	*Rhamnus tomentella* Benth. ssp. *crassifolia* (Jeps.) J.O. Sawyer	Rhamnaceae		
SABI	*Sanicula bipinnata* Hook. & Arn.	Apiaceae	46	0.6
SACR	*Sanicula crassicaulis* Poepp. ex DC.	Apiaceae	40	0.7
SASO	*Salvia sonomensis* Greene	Lamiaceae	40	6.8
SIMA	*Sidalcea malvaeflora* (DC.) A. Gray ex. Benth. ssp. *asprella* (Greene) C.L. Hitchc.	Malvaceae		
SEAR	*Senecio aronicoides* DC.	Asteraceae		
STME	*Stellaria media* (L.) Vill.	Caryophyllaceae		
TACA	*Taeniatherum caput-medusae* (L.) Nevski	Poaceae		
TOAR	*Torilis arvensis* (Huds.) Link	Apiaceae	52	3.8
TODI	*Toxicodendron diversilobum* (Torr. & A. Gray) Greene	Anacardiaceae	53	4.7
TRDU	*Trifolium dubium* Sibth.	Fabaceae		
TRMI	*Trifolium microcephalum* Pursh.	Fabaceae		
TRPR	*Trifolium pratense* L.	Fabaceae		
TRWI	*Trifolium willdenovii* Spreng.	Fabaceae		
VINI	*Vicia sativa* L. ssp. *nigra* L.	Fabaceae		
VIVA	*Vicia villosa* Roth ssp. *varia* (Host) Corb.	Fabaceae		
VUHI	*Vulpia myuros* (L.) C.C. Gmel. *var. hirsute* Hack.	Poaceae		
VUMY	*Vulpia myuros* (L.) C.C. Gmel.	Poaceae	72	2.4
VUPA	*Vulpia microstachys* (Nutt.) Munro var. *pauciflora* (Scribn. ex. Beal) Lonard & Gould	Poaceae		
*WYRE	*Wyethia reticulata* Greene	Asteraceae		

with the cluster "Chaparral 1" (Yellow group in Figure 3; Table 7). Additional shrub species in "Chaparral 1" include *Arctostaphylos viscida* (ARVI), *Ceanothus lemmonii* Parry (CELE), and *Quercus dumosa* Nutt. (QUDM) and low-growing *Salvia sonomensis* (SASO). Four rare species were most abundant in the "Chaparral 1" cluster and closely associated with each other; *Calystegia stebbinsii* (CAST), *Ceanothus roderickii* (CERO), *Chlorogalum grandiflora* (CHGR),

TABLE 5. SUMMARY OF TWINSPAN CLASSIFICATIONS THE 100 MOST FREQUENTLY ENCOUNTERED PLANT TAXA. The listing is arranged into the three main TWINSPAN community types (WOODLAND, SHRUB, GRASSLAND). The three right-hand columns contain the frequency (percentage of plots) of taxa found in shrub-dominated, tree-dominated and open, grassland type plots; frequencies in bold text are plants characteristic of the main community type. Within the main types, TWINSPAN community sub-types are delimited. Species abbreviations as in Table 4. Underlined species are those that occurred in ca. 10% or more plots in each main community type. Plants with an asterisk are rare species among the top 100 species. Plant names followed by "Serp" were found in serpentine plots.

Plant taxa	Native/ Introduced	Life form	Shrub plots	Woodland plots	Grassland plots
			WOODLAND		
				Blue Oak Savanna	
MAGR Serp	N	forb	1.6	**31.6**	5.3
TRWI Serp	N	forb	7.9	**15.8**	7.9
QUDO Serp	N	tree	3.2	**55.3**	21.1
GAAP Serp	I	forb	7.9	**84.2**	18.4
CLPE Serp	N	forb	3.2	**31.6**	10.5
RAOC	N	forb		**34.2**	2.6
CAOL Serp	N	forb	4.8	**23.7**	2.6
CYEC Serp	I	grass	4.8	**78.9**	10.5
SACR Serp	N	forb	11.1	**78.9**	5.3
TOAR Serp	I	forb	12.7	**92.1**	18.4
				Woodland	
AECA	N	tree	1.6	**26.3**	
CLLA Serp	N	vine	1.6	**15.8**	
QUCH Serp	N	tree		**7.9**	
QUWI Serp	N	tree	19.0	**71.1**	2.6
DIVO Serp	N	bulb	3.2	**57.9**	2.6
BRLA	N	grass		**52.6**	
ELGL	N	grass		**68.4**	2.6
LASU	N	forb		**2.6**	7.9
LOHI	N	vine		**39.5**	
LOIN Serp	N	vine	3.2	**36.8**	
LUCO	N	forb		**68.4**	
SIMA	N	forb	1.6	**36.8**	
ACMI	N	forb		**39.5**	
IRMA Serp	N	forb	3.2	**44.7**	
PIPO	N	tree		**23.7**	
QUKE	N	tree		**52.6**	
TODI Serp	N	vine	23.8	**92.1**	
MECA Serp	N	grass	12.7	**47.4**	
* WYRE	N	forb	4.8	**18.4**	
CABR	N	forb	6.3	**15.8**	
MOVI	N	forb	7.9	**28.9**	
				Chaparral-Woodland Transition	
CAAL Serp	N	bulb	47.6	**73.7**	
CEOC	N	tree	9.5	**23.7**	
HEAR Serp	N	shrub	44.4	**71.1**	
RHTO Serp	N	shrub	23.8	**31.6**	
BRDS	I	grass	7.9	**10.5**	
PISA Serp	N	tree	23.8	**26.3**	
PETR Serp	N	fern	19.0	**28.9**	
			SHRUB		
				Short Chaparral	
BRMA Serp	I	grass	**69.8**	65.8	13.2
SABI Serp	N	forb	**39.7**	36.8	15.8
BAPI	N	shrub	**12.7**	15.8	2.6
VUPA Serp	N	grass	**19.0**	13.2	2.6
CEPA Serp	N	shrub	**4.8**	2.6	
CHPO Serp	N	bulb	**15.9**	26.3	
GAPO Serp	N	forb	**81.0**	84.2	
METO Serp	N	grass	**9.5**	18.4	
RHIL Serp	N	shrub	**30.2**	44.7	
ELMU Serp	N	grass	**17.5**	13.2	
ERLA Serp	N	forb	**20.6**	15.8	

TABLE 5. CONTINUED.

Plant taxa	Native/ Introduced	Life form	Shrub plots	Woodland plots	Grassland plots
POCO Serp	N	shrub	**23.8**	28.9	
SEAR	N	forb	**9.5**	18.4	
Tall Closed-Canopy Chaparral					
CECU Serp	N	shrub	**7.9**	5.3	
ADFA Serp	N	shrub	**76.2**	18.4	
ARVI Serp	N	shrub	**74.6**	55.3	
FIGA Serp	I	forb	**14.3**	2.6	
GAVE Serp	I	grass	**54.0**	2.6	
LECA	N	shrub	**27.0**	7.9	
MAEX Serp	N	forb	**30.2**	2.6	
QUDM Serp	N	tree	**15.9**	7.9	
DIMU Serp	N	bulb	**23.8**	5.3	5.3
CELE	N	shrub	**25.4**	10.5	
*CERO	N	shrub	**12.7**	2.6	
* CHGR	N	bulb	**22.2**		
ERCA	N	shrub	**20.6**		
HEMI Serp	N	forb	**46.0**		
SASO	N	forb	**58.7**	5.3	
Open Chaparral					
VUMY Serp	I	grass	**66.7**	34.2	44.7
GADI	I	forb	**19.0**		5.3
AICA Serp	I	grass	**77.8**	50.0	28.9
MICA Serp	N	forb	**14.3**	2.6	
PLER Serp	N	forb	**12.7**		7.9
GRASSLAND					
LOMI Serp	N	forb	11.1	5.3	**18.4**
DICA Serp	N	bulb	20.6	10.5	**31.6**
HYGL Serp	I	forb	25.4	5.3	**50.0**
HYRA Serp	I	forb	11.1		**21.1**
VINI	I	forb		10.5	**42.1**
BRHO Serp	I	grass	15.9	23.7	**97.4**
ERCI	I	forb	1.6		**39.5**
HOMU Serp	I	grass			**26.3**
LUBI Serp	N	forb			**50.0**
TRDU Serp	I	forb	1.6		**44.7**
TRPR Serp	I	forb	1.6	5.3	**57.9**
AETR Serp	I	grass	1.6	2.6	**44.7**
AVFA Serp	I	grass		13.2	**52.6**
BRDI	I	grass		26.3	**68.4**
ERBR Serp	I	forb	1.6		**81.6**
GEDI Serp	I	forb		7.9	**55.3**
LUMU Serp	I	grass		5.3	**39.5**
BREL	N	bulb	4.8	18.4	**60.5**
TACA	I	grass		2.6	**50.0**
VUHI Serp	I	grass	6.3	2.6	**13.2**
HOVI	N	forb			**18.4**
VIVA	I	forb		2.6	**18.4**
BRMI	I	grass	1.6	18.4	**34.2**
CEGL	I	forb	3.2	28.9	**34.2**
GEMO	I	forb	1.6	21.1	**31.6**
AVBA Serp	I	grass	22.2	39.5	**36.8**
BRST Serp	I	grass		31.6	**21.1**
STME	I	forb		21.1	**28.9**
TRMI	N	forb	9.5	21.1	**23.7**

and *Fremontodendron californicum* ssp *decumbens* (FRCA) (Table 8). "Chaparral 1" was found on southerly facing slopes ("Aspt") and was associated with soils derived from serpentine and gabbro that were rocky ("Text"), dry ("H2O"), and CA-poor ("CA") but moderately deep ("Bdrk").

A second high diversity shrub-dominated cluster – "Chaparral 2" (Blue group Fig. 3; Table 7) – was located in CCA space between

TABLE 6. RESULTS OF FORWARD SELECTION IN ORDER OF VARIABLE INCLUSION INTO THE FINAL MODEL. The conditional effects (λ_A) are the additional variance explained by that variable upon its inclusion into the model. All variables contributed significantly to the model (P-value < 0.05). Variable codes follow Table 2.

Variable	λ_A	P-value	F ratio
ShCov	0.58	0.002	14.00
TrCov	0.45	0.002	11.48
NatS	0.19	0.002	5.06
Serp	0.15	0.002	4.22
Chap	0.14	0.002	3.69
Uniq	0.12	0.002	3.42
Elev	0.09	0.002	2.66
Text	0.08	0.002	2.26
Dist	0.08	0.002	2.29
Lati	0.07	0.002	2.16
Dive	0.07	0.002	2.12
Rare	0.07	0.002	2.10
Stor	0.07	0.002	2.00
GrCov	0.06	0.002	1.96
Gabb	0.06	0.002	1.83
Bdrk	0.06	0.002	1.75
Exot	0.05	0.002	1.74
Wood	0.06	0.004	1.72
Slpe	0.05	0.004	1.66
Cov	0.05	0.004	1.67
CA	0.05	0.002	1.60
Shan	0.05	0.026	1.33
Even	0.04	0.018	1.40
Gran	0.05	0.018	1.62

Adenostoma-Arctostaphylos "Chaparral 1" and the "Woodland" communities. Species that characterize "Chaparral 2" were shrubs *Heteromeles arbutifolia* (HEAR), *Cercis occidentalis* (CEOC), and *Rhamnus tomentella* ssp. *crassifolia* (RHTO); the sedge *Carex brainerdii* Mackensie (CABR), and two rare species, *Packera layneae* (PALA) and *Wyethia reticulata* (WYRE). Foothill Pine, *Pinus sabiniana* (PISA) was placed between "Chaparral 2" and "Woodland" (Fig. 3). Environmental variables associated with "Chaparral 2" included steeper slopes than "Chaparral 1", but with more moderate (non-southerly) aspect and higher water availability. This group was strongly associated with other native species, and negatively associated with disturbance, exotic species, and the "Grassland" cluster. Both shrub clusters were associated with higher numbers of families per species ("Dive") than the "Grassland" cluster which was dominated by species in Poaceae.

The "Woodland" cluster (Red group in Fig. 3; Table 7) was associated with north facing slopes, the presence of water, and shallow, metamorphic- or granite-derived soils with high calcium and few surface rocks. Not surprisingly, it was associated with high tree cover ("TrCov"), and high total cover ("Covr"). This cluster was associated with high species diversity ("Shan"), especially native species ("NatS"), and species diversity was homogeneous among plots ("Even"). "Woodland" was negatively associated with disturbance ("Dist").

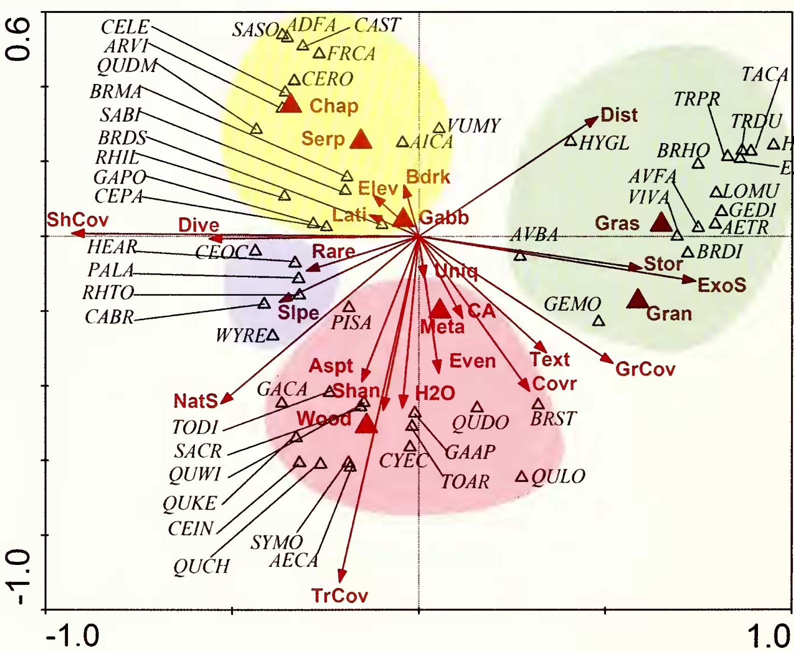

FIG. 3. First two canonical correspondence analysis (CCA) axes depicting biplot scores of the 50 most abundant species (hollow triangles), quantitative (arrows), and nominal (filled triangles) environmental variables. The four clusters of species associations are those corresponding to sites with many introduced species (green), to woodland sites (red), to chaparral type 1 sites (yellow), and to chaparral type 2 sites (blue). See Table 4 for species abbreviations list and Table 2 for list of factors and their abbreviations.

TABLE 7. THE FOUR CLUSTERS OF SPECIES ASSOCIATIONS BASED ON CHI SQUARE DISTANCES FROM THE CCA ON 104 TAXA (COLORS AS IN FIG. 3). Taxa abbreviations as in Table 4. The rare taxa are in bold text. The lower case letters following taxon abbreviations in Chaparral 1 and 2 refer to fire regeneration mechanisms: f = facultative seeder, r = obligate resprouter, r? = potential to resprout suggested by underground perennating structures, s = obligate seeder. (Anderson 1991; Keeley 1991; Hickman 1993; Franklin et al. 2004; personal observation).

Cluster 1 grassland (green)		Cluster 2 woodland (red)		Cluster 3 chaparral 1– xeric seeders (yellow)			Cluster 4 chaparral 2 – mesic resprouters (blue)
AETR	HYRA	ACMI	LUCO	ADFA-f	**CHGR-r**	HEMI	CAAL-r
AVBA	LOMI	AECA	MAGR	AICA	CHPO-r	LECA-s	CABR-r?
AVFA	LOMU	BRLA	PEAZ	ARVI-s	DIMU-r	MAEX	CAOL-r?
BRDI	LUBI	BRST	PIPO	BAPI-r	ELMU	MICA	CEOC-r&s
BREL	SIMA	CLPE	PISA	BRDS	ERCA-r	POCO	CLLA
BRHO	TACA	CYEC	QUCH	BRMA	ERLA	QUDM-r	HEAR-r
BRMI	TRDU	CYGR	QUDO	**CAST-s**	FIGA	RHIL-r	MECA-r?
CEGL	TRMI	DIVO	QUKE	CECU-s	**FRCA-f**	SABI	METO
DICA	TRPR	ELGL	QUWI	CELE-s	GADI	SASO-f	MOVI
ERCI	TRWI	GAAP	RAOC	CEPA	GAPO	VUMY	**PALA-r**
GEDI	VIHI	**GACA**	SACR	**CERO-s**	GAVE	VUPA	PETR-r?
GEMO	VINI	IRMA	SIMA				RHTO-r
HOMU	VIVA	LASU	TOAR				SEAR-r?
HOVI	VUHI	LOHI	TODI				**WYRE-r**
HYGL							

Plants found in this cluster included trees such as the oaks (*Quercus* sp; QUWI, QUKE, QUCH, QUDO, QULO), *Aesculus californica* (Spach.) Nutt. (AECA), and *Pinus ponderosa* (PIPO), vines such as *Toxicodendron diversiloba*, and low growing forbs such as *Galium* spp. including the rare *G. californicum* ssp. *sierrae* (GACA).

Many of the exotic species such as annual grasses *Avena fatua* L., *Bromus diandrus* Roth, *B. hordeaceous* L., *Lolium multiflorum* L., and *Taeniatherum caput-medusae* (L.) Nevski (AVFA, BRDI, BRHO, LOMU, and TACA) and forbs *Trifolium dubium* Sibth., *T. pretense* L., and *Erodium brachycarpum* (Godr.) Thell. (TRDU, TRPR, and ERBR) occurred in the "Grassland" cluster and were top ranked along the disturbance arrow (Green group Fig. 3; Table 8). "Grassland" was associated with granitic soils on generally level sites, and was highest rated for agriculture according to the Storie Index. "Grassland" was negatively associated with shrub cover, plant family diversity, and rare species and strongly associated with Exotic Species ("ExoS"),

Since one of the initial goals of this study was to investigate the existence of plant communities that included rare and endangered plants living upon relatively unique soils, special attention was given to plots that included rare species. Within the plot study, only 19 plots possessed rare taxa; all of those were located in either chaparral or woodland areas of gabbro soils. None of the rare plant species was found in the "Grassland" cluster (Table 7). Of the rare taxa, *Calystegia stebbinsii* (CAST), *Ceanothus roderickii* (CERO), *Chlorogalum grandiflorum* (CHGR), and *Fremontodendron californica* ssp *decumbens* (FRCA) were most abundant in the "Chaparral 1" cluster and closely associated with each other. *Galium californicum* ssp *sierrae* (GACA) was found in the "Woodland" cluster adjacent to "Chaparral 2". *Packera layneae* (PALA) and *Wyethia reticulata* (WYRE) were more abundant in the "Chaparral 2" cluster.

Variance partitioning of biotic sources of variance from abiotic sources revealed that 12.5% of the total species variation was explained by purely abiotic factors and 18.6% by biotic factors (Tables 8 and 9). According to permutation tests, both of these sources of variation were significant ($P = 0.002$) and were of equal weight in explaining variance (at the 5% level). The two categories of variables shared 14.8% of the total species variance.

Partitioning the explanatory variables into spatially explicit (longitude and latitude) and the remaining environmental variables suggested that there may be a small amount of beta diversity among the sites. A linear model of spatial variables explained about 1.3% of the total species variation. An additional 1.1% of the variation was explained jointly by spatial arrangement and the remaining environmental variables. Whereas the full model ($P = 0.002$) explained a significant portion of species variation according to permutation tests, the purely spatial sources ($P = 0.054$) explained only a marginally significant portion.

Species diversity in terms of the Shannon diversity index (H′) tended to be highest on gabbro soils and lowest on metamorphic soils, and was highest in "Woodland" and lowest in "Chaparral" plots (Fig. 4). Species evenness among sites was similar within rock formation groups; "Woodland" and "Grassland" plots were more homogeneous than the chaparral plots.

TABLE 8. VARIANCE EXPLAINED BY ABIOTIC AND BIOTIC FACTORS IN THE PINE HILL FLORA. The trace is the sum of all canonical variables in the analysis. The F ratio and P-values were generated by Monte Carlo permutation tests (see text for details).

Source	Trace	F ratio	P value	% variance
Abiotic ignoring biotic	1.717	3.326	0.002	27.3
Biotic ignoring abiotic	2.104	4.452	0.002	33.4
Both	2.891	3.340	0.002	46.0
Abiotic adjusted for biotic	0.787	1.818	0.002	12.5
Biotic adjusted for abiotic	1.173	2.712	0.002	18.6
Total inertia	6.290			100.0

DISCUSSION

The Pine Hill area stands out as an ecological island of considerable interest due to its diverse flora, vegetation types, rare plant species, and uncommon geology. The 731 species of vascular plants found there and on its borders account for more than 10% of the plant species found in the entire state of California (6,885 species, Hickman 1993) while encompassing less than 0.05% of the area of the entire State. Within this small area we found a diversity of plant forms (ferns, grasses, forbs, shrubs, vines, and trees) within three main community types, many native species including edaphic endemic species, a rich non-native flora, geological and topographic complexity that created numerous habitats, and natural and human-caused disturbances that created temporal diversity. Any or all of these factors interacted to produce an area about 200-fold more diverse on average than the State as a whole.

The distributions of species were related equally to biotic (cover, native species diversity, etc.) and abiotic variables (serpentine soil, soil texture, etc.). Variance in species distributions due to spatial constraints or correlations was small (<2% of variation), which suggests that dispersal limitations have not played a role in community structure at the spatial scale of the Pine Hill gabbro intrusion although dispersal limitations may have played a role at both larger and smaller spatial scales (Bell 2005). TWINSPAN and CCA analysis were in agreement in identifying three basic vegetation types within the study area. The first and most common of these was chaparral shrublands. Overall the chaparral of the study area was rich in terms of native species diversity and had relatively few exotic species. Much of the chaparral was composed of extremely thick stands of *Adenostoma fasciculatum* (chamise) and/or *Arctostaphylos viscida* (whiteleaf manzanita). This type of chaparral occurred on south and southwest facing slopes on gabbro or serpentine soils. A second type of chaparral, denoted by the presence of evergreen shrubs *Heteromeles arbutifolia* and *Rhamnus tomentella*, and deciduous shrub/tree *Cercis occidentalis*, occurred on sites with moderate exposure and was intermediate in our analysis between "Woodland" and "Chaparral.

The two main strategies by which chaparral plants regenerate after fire are vegetative resprouting and recruitment from seeds whose germination is cued by fire. Shrubs such as *Arctostaphylos viscida* and *Ceanothus cuneatus* (Hook.) Nutt. are referred to as obligate seeders as the plants are killed by fire and the species must regenerate from long-lived seed stored in the soil seed bank (Keeley 1987, 1991). While the seedlings are able to exploit the high light, nutrient, and water availability of the post-fire environment in the spring following fire, they are then subject to severe moisture stress during the summer drought. As a consequence, these species have evolved higher tolerance to drought than the seedlings of obligate resprouters (Keeley 1998). Obligate resprouters, such as *Heteromeles arbutifolia* and *Rhamnus tomentella*, are not killed by fire but resprout from underground structures such as lignotubers, roots, and/or rhizomes following fire. They do not depend on fire to cue the germination of their seeds; indeed seeds may be short-lived or killed by fire's heat. However, some resprouters, such as *Wyethia reticulata* (Ayres in press), may not flower until the shrub canopy is removed and thus are indirectly dependant on fire for sexual reproduction. In general, seedlings of resprouting species are less drought tolerant than the seedlings of seeders (Davis et al. 1998; Keeley 1998) and may require shaded, mesic sites for seedling survival, such as under the shrub canopy. Some species, such as *Adenostoma fasciculatum*, are termed "facultative seeders" as they employ both strategies; the plants and seeds both survive fire and thus these species can both resprout and germinate following fire. Based on species response models Meentemeyer et al. (2001) have suggested that limitations on seed germination and seedling survival affect landscape patterns of shrub establishment with fire-dependant seeding species occurring on xeric, exposed slopes, while resprouting species are more common on protected, mesic sites. This interpretation is consistent with the chaparral communities we found.

TABLE 9. VARIANCE DECOMPOSITION OF THE EFFECT OF ABIOTIC AND BIOTIC FACTORS ON GABBRO ASSOCIATED VEGETATION. Computations are based on CCA analyses presented in Table 9 and the components correspond to those depicted in Figure 3.

Component	Source	Variance	Percentage
A	Pure abiotic	0.787	12.5
B	Shared	0.930	14.8
C	Pure biotic	1.173	18.7
D	Residual	3.399	54.0

Our study suggests that there are two distinct chaparral types in what has been previously identified as one community, "Northern Gabbroic Chaparral" (Holland 1986), and more recently as the (*Arctostaphylos viscida – Adenostoma fasciculatum*) / *Salvia sonomensis* Association (Klein et al. 2007). "Chaparral 1", dominated by chamise (ADFA) and manzanita (ARVI) was associated with a harsh set of environmental conditions in the CCA and contained a distinct set of plant species many of which respond to fire by facultative or obligate seeding (Fig. 3, Table 7). We termed this community "Xeric Seeding" to denote the harsh environment and dominant method of fire regeneration. As well, this type of chaparral was identified and classified using TWINSPAN as "Tall Chaparral" (Table 5). "Chaparral 2", identified as a "Chaparral-Woodland" transitional type in TWINSPAN, was characterized in the CCA by more moderate environmental conditions and species that employ a resprouting strategy to survive fire, e.g., evergreen shrub species *Heteromeles arbutifolia* (HEAR), and *Rhamnus tomentella* (RHTO), and deciduous *Cercis occidentalis* which both resprouts following fire (Anderson 1991) and has long-lived seed that survives fire. We termed this type of chaparral "Mesic Reprouting".

"Woodland", the second main woody vegetation type, appeared where the chaparral-covered slopes came together to form a pattern of drainage gullies and stream courses, and extended into the lower and narrower riparian canyons of the region. Woodland vegetation, with occasional elements from higher elevation forest (e.g., *Pinus ponderosa*), followed the pattern of drainage courses and streambeds. In addition to serving as riparian tree cover, woodland vegetation covered the north-facing slopes of the steeper hills and ridges as well. A rich variety of native plant taxa occurred in the "Woodland" and this community had the highest Shannon's H′ diversity index (Fig. 4). In many wooded areas, three structural layers or strata were found: a canopy of overstory trees, an understory layer of shrubs and smaller trees, and an herbaceous ground cover. Like the chaparral, the woodland vegetation varied in density. Some areas were extremely thick and almost impenetrable; these were identified using TWINSPAN as species-rich "Woodland". The upper layer of this vegetation type was usually quite closed, providing cooler micro-climates beneath the canopy of live oaks and vines. Other "Woodland" types were open, park-like meadows of native and exotic forbs with scattered Blue Oaks (QUDO) ("Blue-Oak Savanna", Table 5). Intermediate between "Woodland" and "Shrubland" was a community that contained shrubs typical of "Chaparral 2" and included Foothill Pine (PISA) ("Chaparral-Woodland" Transition Table 5).

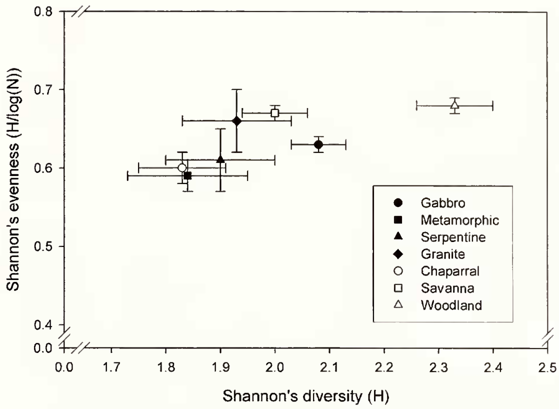

FIG. 4. Shannon's diversity (X-axis) and evenness (Y-axis) for species associations based on soil (solid shapes) and vegetation type (open shapes).

In the wider, open valleys of the region, the chaparral and woodlands gave way to the third basic vegetation type, the grasslands. Most of the species were common exotic annuals (e.g., *Avena* spp. *Bromus* spp., *Erodium* spp., *Lotus* spp., *Trifolium* spp., Tables 5 and 7) that germinated in the fall and early spring, set seed, and were dead by early summer. This species composition was typical of what has been observed in the California foothill grasslands for at least several decades (Bentley and Talbot 1948) with the exception of more recent arrivals, *Aegilops triuncialis* L. and *Taeniatherum caput-medusae*. In the Pine Hill area, this vegetation was strongly associated with high numbers of exotic species, high levels of disturbance, granitic soils, little slope and a high Storie Index. They appeared as open sunny meadows with occasional scattered oaks (*Quercus douglasii*, *Q. wislizenii* and occasionally *Q. lobata* Nee) and California buckeye (*Aesculus californica*) that provided disconnected patches of shade. Past and current grazing practices may maintain this vegetation type (Bentley and Talbot 1948).

Rare Taxa of Pine Hill Area

No single location or vegetation type was found to contain all of the rare plant species. Of the three basic vegetation types in the Pine Hill area, only the exotic-dominated "Grassland" lacked rare plant species. *Calystegia stebbinsii*, *Ceanothus roderickii*, *Galium californicum* ssp. *sierrae*, *Fremontodendron californicum* ssp *decumbens*, and *Wyethia reticulata* were only found on gabbro soils, although *C. stebbinsii* is known to occur on serpentine soils in Nevada County (CNDDB 2008), and *Packera layneae* occurred on three soil types (Table 1). It is not obvious from our analyses why five rare species should be restricted to gabbro-derived soil in El Dorado Co. In fact, serpentine substrate played a larger role in community structuring than gabbro in our CCA analysis. Stringent environmental conditions were associated with both rare (FRCA, CERO, CAST) and widespread (ADFA, ARVI) species; less stringent conditions were similarly associated with both rare (GACA, PALA, WYRE) and widespread species (HEAR, RHTO, TODI). Dispersal limitation may play a role restricting species distributions at the scale of single habitat patches and over broader regional scales where seed movement is infrequent (Bell 2005), but it apparently did not play a large role at the spatial scale of our study. In short, we did not find an explanation for the limited distributions of the rare species.

The rare species have been observed recovering after controlled burns as well as wildfires. Studies of recovery after fires of both types in the Pine Hill area indicated that *Ceanothus roderickii*, *Fremontodendron californicum* ssp. *decumbens*, and *Calystegia stebbinsii* recover from fire through seeds in the soil whose germination is promoted by fire (Boyd 1987, 2007; Nosal 1997) (Table 1). *Calystegia stebbinsii*, a short-lived twining vine with a woody caudex and rhizomes, may also be able to resprout after short-interval fires as has been observed for *C. macrostegia* (Greene) Brummitt, a congener with similar growth traits, in southern California chaparral (Keeley et al. 2006). *Wyethia reticulata* (Boyd 1987; Ayres and Ryan 1997), *Chlorogalum grandiflorum* (personal observation), *Fremontodendron californicum* ssp. *decumbens* (Boyd 1987) and *Packera layneae* (personal observation) can resprout from underground roots, bulbs, or rhizomes after fire.

Significantly, each chaparral type contained a different assemblage of rare species; "Chaparral 1" contained four rare species (CAST, CERO, CHGR, FRCA) while "Chaparral 2" contained two rare species (PALA, WYRE). *Galium californicum* ssp. *sierrae* (GACA) was located in CCA space in the "Woodland" community near the border with "Chaparral 2". While our results were based on only 19 plots containing rare species, recently Gogol-Prokurat analyzed 79 chaparral relevés containing one or more rare plants from the Pine Hill area (Gogol-Prokurat 2009). She found that relevés where "Chaparral 2" plants (e.g., CABR, CEOC, HEAR, RHTO) were present at cumulative cover values of 3% or higher had more occurrences of resprouting species WYRE, PALA, and CHGR, and facultative seeder FRCA than plots that did not contain these mesic chaparral species. CERO and CAST, obligate seeders were found predominantly in xeric Chaparral type 1 relevés.

Thus, the modes of regeneration of the rare species are tied to environmental harshness and the regeneration strategies of diagnostic common shrub species. This association is important for the preservation of these rare plants for the following reasons: 1) both types of chaparral should be targeted for preservation as each potentially contains a different sub-set of rare species; 2) the search for new populations of a particular rare species, especially those species present only in the seed bank, may be facilitated by looking for diagnostic shrub species; 3) while the regeneration of populations of one or possibly two species (CERO and possibly CAST) requires fire, the regeneration of others (WYRE, PALA, CHGR) may be possible with mechanical removal of the shrub canopy to promote flowering, and/or planting seed into the thick litter of established stands (FRCA, see Boyd and Serrafini 1992); and, 4) if artificial populations are deemed necessary, the selection of the appropriate type of chaparral for each species may promote the success of those efforts.

Galium californicum ssp *sierrae* (GACA) was the only rare species not found in chaparral. Much of its biology, including its mode of regeneration following fire, is unknown. Thought to be an oak woodland species, GACA was placed within the *Quercus kelloggii / Arctostaphylos viscida* Provisional Association by Klein et al. (2007), an association that included several of the "Chaparral 2" shrubs identified here (e.g., HEAR, CEOC, and RHTO) and rare perennial *Wyethia reticulata* (Fig. 3). Of note, after a 2007 fire *G. californicum* ssp *sierra* was observed resprouting near fire-killed trunks of *Q. kelloggii* trees in a community that contained resprouting *Packera layneae*, *W. reticulata*, *Heteromeles arbutifolia*, and reseeding *Cercis occidentalis* – plants of or in close association to "Chaparral 2" vegetation. This occurrence suggests that the native community of this tiny plant may be more like "Chaparral 2" than oak woodland.

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APPENDIX 1

FLORA OF PINE HILL, EL DORADO COUNTY, CALIFORNIA. Determination of taxa in the flora comes from the following sources: N = Newberry (1972), R = Stebbins and Smith (1960), S = Stebbins (1978), V = Van Ess (unpublished plant list), and W = Wilson (this paper). Determination of native (N) or introduced (I) status of plants found in the plot study is from Hickman (1993). Occurrence of listed plants on specific substrate (Rock) is as follows: G = found on gabbro related and possibly other soils, NG = found on non-gabbro soils only, and — = insufficient information, substrate unknown.

Family	Taxon	Native or introduced	Source	Rock
Aceraceae	*Acer macrophyllum* Pursh	N	WNS	G
Aizoaceae	*Cypselea humifusa* Turp.		V	NG
Aizoaceae	*Mollugo verticillata* L.		V	G
Alismataceae	*Alisma plantago-aquatica* L.		WV	G
Amaranthaceae	*Amaranthus californicus* (Moq.) S.Watson		V	G
Anacardiaceae	*Rhus trilobata* Nutt.	N	WVN	G
Anacardiaceae	*Toxicodendron diversilobum* (Torr. & A.Gray) Greene	N	WVNSR	G
Apiaceae	*Anthriscus caucalis* M.Bieb.		VN	G
Apiaceae	*Apiastrum angustifolium* Nutt.		VS	G
Apiaceae	*Daucus carota* L.	N	WV	G
Apiaceae	*Daucus pusillus* Michx.		WVN	G
Apiaceae	*Eryngium vaseyi* J.M.Coult. & Rose var. *vallicola* (Jeps.) Munz		V	NG
Apiaceae	*Foeniculum vulgare* Mill.		VN	G
Apiaceae	*Lomatium macrocarpum* (Nutt. ex Torr. & A.Gray) J.M.Coult. & Rose		WV	G
Apiaceae	*Lomatium marginatum* (Benth.) J.M.Coult. & Rose	N	WVS	G
Apiaceae	*Lomatium utriculatum* (Nutt. ex Torr. & A.Gray) J.M.Coult. & Rose	N	WVN	G
Apiaceae	*Osmorhiza chilensis* Hook. & Arn.	N	W	NG
Apiaceae	*Perideridia gairdneri* (Hook. & Arn.) Mathias	N	WV	G
Apiaceae	*Perideridia kelloggii* (A.Gray) Mathias		VN	G
Apiaceae	*Perideridia parishii* (J.M.Coult. & Rose) A.Nelson & J.F.Macbr.		V	G
Apiaceae	*Sanicula bipinnata* Hook. & Arn.		NR	G
Apiaceae	*Sanicula bipinnatifida* Douglas ex Hook.	N	WVNS	G
Apiaceae	*Sanicula crassicaulis* Poepp. ex DC.	N	WVSR	G
Apiaceae	*Sanicula tuberosa* Torr.	N	WVR	G
Apiaceae	*Scandix pectin-veneris* L.	I	WVNR	G
Apiaceae	*Tauschia hartwegii* (A.Gray) J.F.Macbr.	N	WVNS	G
Apiaceae	*Torilis arvensis* (Huds.) Link	I	WV	G
Apiaceae	*Torilis nodosa* (L.) Gaertn.	I	WV	G
Apiaceae	*Yabea microcarpa* (Hook. & Arn.) Koso-Pol.		N	—
Apocynaceae	*Apocynum cannabinum* L.	N	W	NG
Apocynaceae	*Vinca major* L.		W	G
Aristolochiaceae	*Aristolochia californica* Torr.	N	WVNS	G
Aristolochiaceae	*Asarum hartwegii* S.Watson	N	W	NG
Asclepiadaceae	*Asclepias cordifolia* (Benth.) Jeps.	N	WVSR	G
Asclepiadaceae	*Asclepias fascicularis* Decne.		WVN	G
Asteraceae	*Achillea millefolium* L.	N	WVNSR	G
Asteraceae	*Achyrachaena mollis* Schauer		WNR	G
Asteraceae	*Agoseris grandiflora* (Nutt.) Greene	N	WV	G
Asteraceae	*Agoseris heterophylla* (Nutt.) Greene	N	WVNR	G
Asteraceae	*Agoseris retrorsa* (Benth.) Greene	N	WVR	G
Asteraceae	*Ambrosia psilostachya* DC.		WVS	G
Asteraceae	*Anaphalis margaritacea* (L.) Benth. & Hook.f.		N	—
Asteraceae	*Anthemis cotula* L.		WVN	G
Asteraceae	*Artemisia douglasiana* Besser	N	WVNS	G
Asteraceae	*Aster chilensis* Nees	N	WVN	G
Asteraceae	*Aster radulinus* A.Gray	N	WVR	G
Asteraceae	*Baccharis pilularis* DC. ssp. *consanguinea* (DC.) C.B.Wolf	N	WVNS	G
Asteraceae	*Balsamorhiza deltoidea* Nutt.	N	WVNR	G
Asteraceae	*Balsamorhiza macrolepis* Sharp		N	—
Asteraceae	*Bidens frondosa* L.		V	G
Asteraceae	*Brickellia californica* (Torr. & A.Gray) A.Gray		VNS	G

Appendix 1. Continued.

Family	Taxon	Native or introduced	Source	Rock
Asteraceae	*Calycadenia multiglandulosa* DC.	N	WVNR	G
Asteraceae	*Calycadenia truncata* DC.	N	WVN	NG
Asteraceae	*Carduus pycnocephalus* L.	I	WV	G
Asteraceae	*Centaurea melitensis* L.	I	WV	G
Asteraceae	*Centaurea solstitialis* L.	I	WVNSR	G
Asteraceae	*Chaenactis glabriuscula* DC.	N	WVN	NG
Asteraceae	*Chamomilla suaveolens* (Pursh) Rydb.		WVNSR	G
Asteraceae	*Chondrilla juncea* L.	I	WV	G
Asteraceae	*Cichorium intybus* L.		WN	G
Asteraceae	*Cirsium andersonii* (A.Gray) Petr.		R	G
Asteraceae	*Cirsium occidentale* (Nutt.) Jeps. var. *californicum* (A.Gray) Keil & C.Turner	N	WVNS	G
Asteraceae	*Cirsium occidentale* (Nutt.) Jeps. var. *occidentale*		V	NG
Asteraceae	*Cirsium vulgare* (Savi) Ten.		VNSR	G
Asteraceae	*Conyza canadensis* (L.) Cronquist		VS	G
Asteraceae	*Ericameria arborescens* (A.Gray) Greene	N	WVNR	G
Asteraceae	*Erigeron foliosus* Nutt.		VNSR	G
Asteraceae	*Erigeron inornatus* (A.Gray) A.Gray		W	G
Asteraceae	*Erigeron philadelphicus* L.		V	G
Asteraceae	*Eriophyllum lanatum* (Pursh) Forbes var. *grandiflorum* (A.Gray) Jeps.	N	WVNS	G
Asteraceae	*Filago californica* Nutt.	N	WVS	G
Asteraceae	*Filago gallica* L.	I	WVSR	G
Asteraceae	*Gnaphalium californicum* DC.	N	WVS	G
Asteraceae	*Gnaphalium canescens* DC. ssp. *beneolens* (Davidson) Stebbins & Keil		V	G
Asteraceae	*Gnaphalium canescens* DC. ssp. *microcephalum* (Nutt.) Stebbins & Keil		WV	G
Asteraceae	*Gnaphalium luteoalbum* L.		VS	G
Asteraceae	*Gnaphalium palustre* Nutt.	N	WV	G
Asteraceae	*Gnaphalium purpureum* L.	N	WV	G
Asteraceae	*Grindelia camporum* Greene	N	WVNR	G
Asteraceae	*Grindelia procera* Greene	N	W	G
Asteraceae	*Helenium puberulum* DC.		W	G
Asteraceae	*Helianthus californicus* DC. var. *nevadensis* (Greene) Jeps.		VSR	G
Asteraceae	*Helianthus annuus* L. ssp. *lenticularis* (Douglas ex Lindl.) Cockerell		N	—
Asteraceae	*Helianthus californicus* DC.		VNS	G
Asteraceae	*Hemizonia fitchii* A.Gray	N	WVN	G
Asteraceae	*Hesperevax acaulis* (Kellogg) Greene	N	WV	G
Asteraceae	*Hesperevax sparsiflora* (A.Gray) Greene		S	G
Asteraceae	*Heterotheca grandiflora* Nutt.		VNS	G
Asteraceae	*Holocarpha virgata* (A.Gray) D.D.Keck	N	WVN	G
Asteraceae	*Holozonia filipes* (Hook. & Arn.) Greene		V	G
Asteraceae	*Hypochaeris glabra* L.	I	WVSR	G
Asteraceae	*Hypochaeris radicata* L.	I	W	G
Asteraceae	*Lactuca saligna* L.		V	G
Asteraceae	*Lactuca serriola* L.	I	WVNS	G
Asteraceae	*Lagophylla glandulosa* A.Gray		WV	G
Asteraceae	*Lagophylla ramosissima* Nutt.	N	V	G
Asteraceae	*Lasthenia californica* DC. ex Lindl.	N	WVN	G
Asteraceae	*Layia fremontii* (Torr. & A.Gray) A.Gray		VN	NG
Asteraceae	*Layia pentachaeta* A.Gray		N	—
Asteraceae	*Leontodon taraxacoides* (Vill.) Mérat		V	G
Asteraceae	*Lessingia leptoclada* A.Gray		V	NG
Asteraceae	*Lessingia nemaclada* Greene		V	G
Asteraceae	*Lessingia virgata* A.Gray		V	NG
Asteraceae	*Madia elegans* D.Don ex Lindl.	N	WVNSR	G
Asteraceae	*Madia elegans* D.Don ex Lindl. ssp. *densifolia* (Greene) D.D.Keck		V	G
Asteraceae	*Madia elegans* D. Don ex Lindl. ssp. *vernalis* D.D.Keck		V	G
Asteraceae	*Madia exigua* (Sm.) A.Gray	N	VW	G

APPENDIX 1. CONTINUED.

Family	Taxon	Native or introduced	Source	Rock
Asteraceae	*Madia gracilis* (Sm.) D.D.Keck & J.C.Clausen ex Applegate	N	VW	G
Asteraceae	*Madia minima* (A.Gray) D.D.Keck		R	G
Asteraceae	*Madia rammii* Greene		N	—
Asteraceae	*Madia subspicata* D.D.Keck		V	G
Asteraceae	*Micropus californicus* Fisch. & C.A.Mey.	N	WVNSR	G
Asteraceae	*Microseris acuminata* Greene		V	G
Asteraceae	*Microseris sylvatica* (Benth.) A.Gray		V	G
Asteraceae	*Packera layneae* (Greene) W.A.Weber and Á.Löve	N	WVR	G
Asteraceae	*Pseudobahia heermannii* (Durand) Rydb.	N	WV	G
Asteraceae	*Psilocarphus brevissimus* Nutt.		V	G
Asteraceae	*Psilocarphus tenellus* Nutt.		WS	NG
Asteraceae	*Rafinesquia californica* Nutt.		V	G
Asteraceae	*Rigiopappus leptocladus* A.Gray	N	WV	G
Asteraceae	*Senecio aronicoides* DC.	N	WVR	G
Asteraceae	*Senecio flaccidus* Less. var. *douglasii* (DC.) B.L.Turner & T.M.Barkley		VN	G
Asteraceae	*Senecio vulgaris* L.	I	WVNSR	G
Asteraceae	*Silybum marianum* (L.) Gaertn.	I	WVN	G
Asteraceae	*Solidago californica* Nutt.		VNSR	G
Asteraceae	*Solidago canadensis* L. ssp. *elongata* (Nutt.) D.D.Keck		W	G
Asteraceae	*Solidago occidentalis* Nutt.		V	G
Asteraceae	*Soliva sessilis* Ruiz & Pav.		WV	G
Asteraceae	*Sonchus asper* (L.) Hill	I	WVNSR	G
Asteraceae	*Sonchus oleraceus* L.		VS	G
Asteraceae	*Stebbinsoseris heterocarpa* (Nutt.) K.L.Chambers	N	WVSR	G
Asteraceae	*Stephanomeria virgata* Benth.		V	G
Asteraceae	*Stylocline filaginea* (A.Gray) A.Gray	N	WV	G
Asteraceae	*Stylocline gnaphalioides* Nutt.		W	G
Asteraceae	*Taraxacum officinale* F.H.Wigg.		W	NG
Asteraceae	*Tragopogon dubius* Scop.		W	G
Asteraceae	*Tragopogon pratensis* L.		V	G
Asteraceae	*Wyethia angustifolia* (DC.) Nutt.	N	WVR	G
Asteraceae	*Wyethia bolanderi* (A.Gray) W.A.Weber	N	WVSR	G
Asteraceae	*Wyethia helenioides* (DC.) Nutt.		VN	G
Asteraceae	*Wyethia reticulata* Greene	N	WVR	G
Asteraceae	*Xanthium strumarium* L.		WN	G
Berberidaceae	*Berberis aquifolium* Pursh var. *dictyota* (Jeps.) Jeps.	N	WVNR	G
Betulaceae	*Alnus rhombifolia* Nutt.	N	WVNS	G
Blechnaceae	*Woodwardia fimbriata* Sm.		WV	G
Boraginaceae	*Amsinckia menziesii* (Lehm.) A.Nelson & J.F.Macbr.	N	WVSR	G
Boraginaceae	*Amsinckia menziesii* (Lehm.) A.Nelson & J.F.Macbr. var. *intermedia* (Fisch. & C.A.Mey.) Ganders	N	WVNR	G
Boraginaceae	*Cryptantha flaccida* (Douglas ex Lehm.) Greene		V	NG
Boraginaceae	*Cryptantha intermedia* (A.Gray) Greene	N	V	G
Boraginaceae	*Cryptantha micrantha* (Torr.) I.M.Jonst.	N	W	G
Boraginaceae	*Cryptantha muricata* (Hook. & Arn.) A.Nelson & J.F.Macbr.	N	W	NG
Boraginaceae	*Cryptantha muricata* (Hook. & Arn.) A.Nelson & J.F.Macbr. var. *denticulata* (Greene) I.M.Johnst.		V	G
Boraginaceae	*Cynoglossum grande* Douglas ex Lehm.	N	WVNR	G
Boraginaceae	*Myosotis discolor* Pers.		WN	G
Boraginaceae	*Pectocarya pusilla* (A.DC.) A.Gray		VR	G
Boraginaceae	*Plagiobothrys canescens* Benth.		V	NG
Boraginaceae	*Plagiobothrys fulvus* (Hook. & Arn.) I.M.Johnst. var. *campestris* (Greene) I.M.Johnst.	N	V	G
Boraginaceae	*Plagiobothrys nothofulvus* (A.Gray) A.Gray	N	WVNSR	G
Boraginaceae	*Plagiobothrys stipitatus* (Greene) I.M.Johnst. var. *micranthus* (Piper) I.M.Johnst.		V	G
Boraginaceae	*Plagiobothrys tenellus* (Nutt. ex Hook.) A.Gray	N	W	G
Brassicaceae	*Arabidopsis thaliana* (L.) Heynh.	I	WV	G
Brassicaceae	*Arabis sparsiflora* Nutt.		W	NG
Brassicaceae	*Athysanus pusillus* (Hook.) Greene		V	G

Appendix 1. Continued.

Family	Taxon	Native or introduced	Source	Rock
Brassicaceae	*Barbarea verna* (Mill.) Asch.	I	WVG	G
Brassicaceae	*Brassica rapa* L.		WVNG	G
Brassicaceae	*Capsella bursa-pasturis* (L.) Medik.	I	WVNR	G
Brassicaceae	*Cardamine oligosperma* Nutt.	N	WVNS	G
Brassicaceae	*Draba verna* L.		WV	G
Brassicaceae	*Erysimum capitatum* (Douglas ex Hook.) Greene		VS	G
Brassicaceae	*Hirshfeldia incana* (L.) Lagr.-Foss.	I	WVSR	G
Brassicaceae	*Lepidium nitidum* Nutt.	N	WV	G
Brassicaceae	*Lepidium oblongum* Small		V	G
Brassicaceae	*Lepidium strictum* (S.Watson) Rattan		S	G
Brassicaceae	*Raphanus raphanistrum* L.		WN	NG
Brassicaceae	*Raphanus sativus* L.	I	WN	G
Brassicaceae	*Rorippa curvisiliqua* (Hook.) Besser ex Britton		WVS	G
Brassicaceae	*Rorippa nasturtium-aquaticum* (L.) Hayek		WVN S	G
Brassicaceae	*Rorippa palustris* (L.) Besser var. *occidentalis* (S.Watson) Rollins		W	NG
Brassicaceae	*Sisymbrium altissimum* L.		V	G
Brassicaceae	*Sisymbrium irio* L.		N	—
Brassicaceae	*Streptanthus polygaloides* A.Gray	N	WVN	G
Brassicaceae	*Thysanocarpus curvipes* Hook.	N	WVNS	G
Brassicaceae	*Thysanocarpus curvipes* Hook. var. *elegans* (Fisch. & C.A.Mey.) B.Rob.		WV	NG
Brassicaceae	*Thysanocarpus radians* Benth.	N	W	G
Brassicaceae	*Tropidocarpum gracile* Hook.	N	WV	G
Callitrichaceae	*Callitriche verna* L.		V	G
Campanulaceae	*Githopsis pulchella* Vatke	N	WVR	G
Campanulaceae	*Githopsis specularioides* Nutt.	N	WVNR	G
Campanulaceae	*Heterocodon rariflorum* Nutt.	N	WV	G
Campanulaceae	*Triodanis biflora* (Ruiz & Pav.) Greene		V	G
Caprifoliaceae	*Lonicera hispidula* (Lindl.) Douglas ex Torr. & A.Gray var. *vacillans* A.Gray	N	WN	G
Caprifoliaceae	*Lonicera interrupta* Benth.	N	WVNS	G
Caprifoliaceae	*Sambucus mexicana* C.Presl ex DC.		WVN	G
Caprifoliaceae	*Symphoricarpos albus* (L.) S.F.Blake var. *laevigatus* (Fernald) S.F.Blake	N	WVNR	G
Caprifoliaceae	*Symphoricarpos mollis* Nutt.	N	WV	G
Caprifoliaceae	*Virburnum ellipticum* Hook.	N	W	NG
Caryophyllaceae	*Cerastium glomeratum* Thuill.	I	WVSMR	G
Caryophyllaceae	*Lychnis coronaria* (L.) Desr.		S	G
Caryophyllaceae	*Minuartia californica* (A.Gray) Mattf.	N	WV	G
Caryophyllaceae	*Minuartia douglasii* (Fenzl ex Torr. & A.Gray) Mattf.	N	WV	G
Caryophyllaceae	*Petrorhagia dubia* (Raf.) G.López & Romo	N	WVNSR	G
Caryophyllaceae	*Sagina apetala* L. var. *barbata* Fenzl.		W	NG
Caryophyllaceae	*Saponaria officinalis* L.		VNS	G
Caryophyllaceae	*Scleranthus annuus* L.		WVSR	G
Caryophyllaceae	*Silene antirrhina* L.	N	WV	G
Caryophyllaceae	*Silene californica* Durand	N	WN	NG
Caryophyllaceae	*Silene gallica* L.	I	WVNSR	G
Caryophyllaceae	*Spergula arvensis* L.		WV	G
Caryophyllaceae	*Spergula rubra* (L.) J.Presl & C.Presl		V	G
Caryophyllaceae	*Stellaria media* (L.) Vill.	I	WVNS	G
Caryophyllaceae	*Stellaria nitens* Nutt.		S	G
Caryophyllaceae	*Velezia rigida* L.		V	G
Chenopodiaceae	*Chenopodium ambrosioides* L.		W	G
Cistaceae	*Helianthemum scoparium* Nutt.	N	WVR	G
Cistaceae	*Helianthemum suffrutescens* Schreib.		VS	G
Convolvulaceae	*Calystegia occidentalis* (A.Gray) Brummitt		VNSR	G
Convolvulaceae	*Calystegia purpurata* (Greene) Brummitt ssp. *saxicola* (Eastw.) Brummitt	N	W	G
Convolvulaceae	*Calystegia stebbinsii* Brummitt	N	WVR	G
Convulvulaceae	*Convolvulus arvensis* L.		WVNR	G
Cornaceae	*Cornus glabrata* Benth.	N	WVN	G
Crassulaceae	*Crassula connata* (Ruiz & Pav.) A.Berger	N	WS	G

APPENDIX 1. CONTINUED.

Family	Taxon	Native or introduced	Source	Rock
Crassulaceae	*Crassula tillaea* Lester-Garland	N	WVS	G
Crassulaceae	*Dudleya cymosa* (Lem.) Britton & Rose	N	WVNS	G
Crassulaceae	*Parvisedum congdonii* (Eastw.) R.T.Clausen		V	NG
Crassulaceae	*Parvisedum pumilum* (Benth.) R.T.Clausen		N	—
Crassulaceae	*Sedum spathulifolium* Hook.		N	—
Cucurbitaceae	*Marah fabaceus* (Naudin) Naudin ex Greene var. *agrestis* (Greene) Stocking	N	WVN	G
Cucurbitaceae	*Marah watsonii* (Cogn.) Greene	N		
Cupressaceae	*Calocedrus decurrens* (Torr.) Florin		WVNS	G
Cuscutaceae	*Cuscuta californica* Hook. & Arn.	N	WV	G
Cuscutaceae	*Cuscuta californica* Hook. & Arn. var. *breviflora* Engelm.		V	G
Cyperaceae	*Carex athrostachya* Olney		V	G
Cyperaceae	*Carex barbarae* Dewey		V	G
Cyperaceae	*Carex brainerdii* Mack.	N	WVR	G
Cyperaceae	*Carex densa* (L.H.Bailey) L.H.Bailey		V	G
Cyperaceae	*Carex dudleyi* Mack.		V	G
Cyperaceae	*Carex gracilior* Mack.		V	G
Cyperaceae	*Carex nebrascensis* Dewey		S	G
Cyperaceae	*Carex nudata* W.Boott		S	G
Cyperaceae	*Carex praegracilis* W.Boott		V	NG
Cyperaceae	*Carex rossii* Boott		R	G
Cyperaceae	*Carex senta* Boott		V	G
Cyperaceae	*Carex subbracteata* Mack.		V	NG
Cyperaceae	*Cyperus eragrostis* Lam.		VS	G
Cyperaceae	*Cyperus rotundus* L.		V	G
Cyperaceae	*Cyperus squarrosus* L.		V	NG
Cyperaceae	*Eleocharis acicularis* (L.) Roem. & Schult.		V	NG
Cyperaceae	*Eleocharis pachycarpa* Desv.		V	G
Cyperaceae	*Lipocarpha micrantha* (Vahl.) G.Tucker var. *minor* (Schrad.) Friedl.		V	NG
Cyperaceae	*Scirpus acutus* Muhl. ex Bigelow var. *occidentalis* (S.Watson) Beetle		WN	G
Datiscaceae	*Datisca glomerata* (C.Presl) Baill.		VS	G
Dipsacaceae	*Dipsacus fullonum* L.		N	—
Dryopteridaceae	*Dryopteris arguta* (Kaulf.) Watt	N	WVN	G
Equisetaceae	*Equisetum arvense* L.		WVS	G
Equisetaceae	*Equisetum hyemale* L. ssp. *affine* (Engelm.) A.A.Eaton		S	G
Equisetaceae	*Equisetum laevigatum* A.Braun		na	na
Ericaceae	*Arbutus menziesii* Pursh	N	WN	NG
Ericaceae	*Arctostaphylos manzanita* Parry		N	—
Ericaceae	*Arctostaphylos viscida* Parry	N	WVNSR	G
Ericaceae	*Rhododendron occidentale* (Torr. & A.Gray) A.Gray		WVS	G
Euphorbiaceae	*Chamaesyce maculata* (L.) Small		NV	G
Euphorbiaceae	*Chamaesyce ocellata* (Durand & Hilg.) Small		V	NG
Euphorbiaceae	*Chamaesyce serpyllifolia* (Pers.) Small		V	G
Euphorbiaceae	*Eremocarpus setigerus* (Hook.) Benth.	N	WVN	G
Euphorbiaceae	*Euphorbia crenulata* Engelm.		NSR	G
Euphorbiaceae	*Euphorbia spathulata* Lam.	N	WV	G
Fabaceae	*Astragalus gambelianus* Sheldon	N	WVS	G
Fabaceae	*Cercis occidentalis* Torr. ex A.Gray	N	WVNSR	G
Fabaceae	*Cytisus scoparius* (L.) Link		WVNS	G
Fabaceae	*Hoita macrostachya* (DC.) Rydb.		VS	G
Fabaceae	*Hoita orbicularis* (Lindl.) Rydb.		V	G
Fabaceae	*Lathyrus jepsonii* Greene var. *californicus* (S.Watson) C.L.Hitchc.	N	WV	G
Fabaceae	*Lathyrus latifolius* L.		N	—
Fabaceae	*Lathyrus nevadensis* S.Watson	N	WVN	G
Fabaceae	*Lathyrus sulphureus* W.H.Brewer ex A.Gray	N	WVNSR	G
Fabaceae	*Lotus grandiflorus* (Benth.) Greene	N	WVNS	G
Fabaceae	*Lotus humistratus* Greene	N	WVSR	G
Fabaceae	*Lotus micranthus* Benth.	N	WVSR	G
Fabaceae	*Lotus purshianus* (Benth.) Clem. & E.G.Clem.	N	WVNSR	G

APPENDIX 1. CONTINUED.

Family	Taxon	Native or introduced	Source	Rock
Fabaceae	*Lotus scoparius* (Nutt.) Ottley	N	WVNS	G
Fabaceae	*Lotus wrangelianus* Fisch. & C.A.Mey.		WR	G
Fabaceae	*Lupinus albifrons* Benth.	N	WVNSR	G
Fabaceae	*Lupinus benthamii* A.Heller		VNS	G
Fabaceae	*Lupinus bicolor* Lindl.	N	WVNSR	G
Fabaceae	*Lupinus bicolor* Lindl. ssp. *microphyllus* (S.Watson) D.Dunn		V	G
Fabaceae	*Lupinus bicolor* Lindl. ssp. *pipersmithii* (A.Heller) D.Dunn		V	G
Fabaceae	*Lupinus latifolius* Lindl. ex J.Agardh	N	R	G
Fabaceae	*Lupinus latifolius* Lindl. ex J.Agardh var. *columbianus* (A.Heller) C.P.Sm.		WVN	G
Fabaceae	*Lupinus microcarpus* Sims var. *densiflorus* (Benth.) Jeps.		WV	G
Fabaceae	*Lupinus microcarpus* Sims		VN	G
Fabaceae	*Lupinus nanus* Douglas ex Benth.	N	WVRS	G
Fabaceae	*Lupinus polyphyllus* Lindl.		R	G
Fabaceae	*Medicago polymorpha* L.	I	WVR	G
Fabaceae	*Melilotus indica* (L.) All.		WVN	G
Fabaceae	*Melilotus officinalis* (L.) Lam.		WVNS	G
Fabaceae	*Pickeringia montana* Nutt.		VN	G
Fabaceae	*Robinea pseudoacacia* L.		N	—
Fabaceae	*Rupertia physoides* (Douglas ex Hook.) Grimes		W	G
Fabaceae	*Trifolium albopurpureum* Torr. & A.Gray		V	G
Fabaceae	*Trifolium albopurpureum* Torr. & A.Gray var. *olivaceum* (Greene) Isely		V	NG
Fabaceae	*Trifolium barbigerum* Torr.		V	NG
Fabaceae	*Trifolium bifidum* A.Gray var. *decipiens* Greene	N	WVR	G
Fabaceae	*Trifolium bifidum* A.Gray		V	G
Fabaceae	*Trifolium ciliolatum* Benth.	N	WVR	G
Fabaceae	*Trifolium depauperatum* Desv.	N	WV	G
Fabaceae	*Trifolium dubium* Sibth.	I	WVSR	G
Fabaceae	*Trifolium glomeratum* L.		V	G
Fabaceae	*Trifolium gracilentum* Torr. & A.Gray		V	G
Fabaceae	*Trifolium hirtum* All.		S	G
Fabaceae	*Trifolium incarnatum* L.		VN	G
Fabaceae	*Trifolium microcephalum* Pursh	N	WVSR	G
Fabaceae	*Trifolium microdon* Hook. & Arn.	N	W	G
Fabaceae	*Trifolium pratense* L.	I	WVN	G
Fabaceae	*Trifolium subterraneum* L.	I	WV	G
Fabaceae	*Trifolium variegatum* Nutt.		WV	G
Fabaceae	*Trifolium wildenovii* Spreng.	N	WVSR	G
Fabaceae	*Vicia americana* Muhl. ex Willd.		WVR	G
Fabaceae	*Vicia benghalensis* L.		V	G
Fabaceae	*Vicia hirsuta* (L.) Gray	I	W	NG
Fabaceae	*Vicia sativa* L.	I	WVN	G
Fabaceae	*Vicia sativa* L. ssp. *nigra* (L.) Ehrh.	I	WVNSR	G
Fabaceae	*Vicia villosa* Roth	I		G
Fabaceae	*Vicia villosa* Roth ssp. *varia* (Host) Corb.	I	WV	G
Fagaceae	*Quercus chrysolepis* Liebm.	N	WNS	G
Fagaceae	*Quercus douglasii* Hook. & Arn.	N	WVNSR	G
Fagaceae	*Quercus dumosa* Nutt.	N	WVNSR	G
Fagaceae	*Quercus durata* Jeps.	N	WVNSR	G
Fagaceae	*Quercus kelloggii* Newberry	N	WVNR	G
Fagaceae	*Quercus lobata* Née	N	WVNR	G
Fagaceae	*Quercus wislizenii* A.DC.	N	WVNSR	G
Fagaceae	*Quercus* × *morehu* Kellogg		N	—
Garryaceae	*Garrya congdonii* Eastw.	N	WVN	G
Garryaceae	*Garrya fremontii* Torr.		N	—
Gentinaceae	*Centaurium muehlenbergii* (Griseb.) W.Wight ex Piper	N	WVS	G
Gentinaceae	*Centuarium venustum* (A.Gray) Rob		V	G
Gentinaceae	*Swertia albicaulis* (Douglas ex Griseb.) Kuntze var. *nitida* (Benth.) Jeps.	N	WVR	G

APPENDIX 1. CONTINUED.

Family	Taxon	Native or introduced	Source	Rock
Geraniaceae	*Erodium botrys* (Cav.) Bertol.		WVSR	G
Geraniaceae	*Erodium brachycarpum* (Godr.) Thell.	I	WVNS	G
Geraniaceae	*Erodium cicutarium* (L.) L'Hér. ex Aiton	I	WVNSR	G
Geraniaceae	*Erodium moschatum* (L.) L'Hér. ex Aiton	I	WV	G
Geraniaceae	*Geranium carolinianum* L.		VN	G
Geraniaceae	*Geranium dissectum* L.	I	WVS	G
Geraniaceae	*Geranium molle* L.	I	WVSR	G
Hippocastanaceae	*Aesculus californica* (Spach) Nutt.	N	WVNSR	G
Hydrophyllaceae	*Emmenanthe penduliflora* Benth.	N	WVR	G
Hydrophyllaceae	*Eriodictyon californicum* (Hook. & Arn.) Torr.	N	WVNSR	G
Hydrophyllaceae	*Nemophila heterophylla* Fisch. & C.A.Mey.	N	WVNS	G
Hydrophyllaceae	*Nemophila maculata* Benth. ex Lindl.		VN	G
Hydrophyllaceae	*Nemophila menziesii* Hook. & Arn.		VN	G
Hydrophyllaceae	*Phacelia cicutaria* Greene		NS	G
Hydrophyllaceae	*Phacelia imbricata* Greene		VS	G
Hypericaceae	*Hypericum concinnum* Benth.	N	WVSR	G
Hypericaceae	*Hypericum mutilum* L.		N	—
Hypericaceae	*Hypericum perforatum* L.	I	WVNS	G
Iridaceae	*Iris hartwegii* Baker		NR	G
Iridaceae	*Iris macrosiphon* Torr.	N	WVNSR	G
Iridaceae	*Sisyrinchium bellum* S.Watson	N	WVNR	G
Juglandaceae	*Juglans californica* S.Watson var. *hindsii* Jeps.		WVN	G
Juncaceae	*Juncus balticus* Willd.		V	G
Juncaceae	*Juncus bufonius* L.	N	WVS	G
Juncaceae	*Juncus effusus* L. var. *pacificus* Fernald & Wiegand		V	G
Juncaceae	*Juncus nevadensis* S.Watson		V	G
Juncaceae	*Juncus oxymeris* Engelm.		V	G
Juncaceae	*Juncus tenuis* Willd.		V	G
Juncaceae	*Luzula comosa* E.Mey.	N	WVSR	G
Lamiaceae	*Lamium amplexicaule* L.	I	WR	G
Lamiaceae	*Lamium purpureum* L.	I	W	NG
Lamiaceae	*Lepechinia calycina* (Benth.) Epling ex Munz	N	WVNR	G
Lamiaceae	*Lycopus americanus* Muhl ex W.Bartram		V	G
Lamiaceae	*Marrubium vulgare* L.		WVN	G
Lamiaceae	*Mentha aquatica* L.		V	G
Lamiaceae	*Mentha arvensis* L. var. *villosa* (Benth.) S.R.Stewart		V	G
Lamiaceae	*Mentha piperita* L.		V	G
Lamiaceae	*Mentha pulegium* L.		W	G
Lamiaceae	*Mentha spicata* L.		VS	G
Lamiaceae	*Monardella villosa* Benth. ssp. *villosa*	N	WVN	G
Lamiaceae	*Monardella viridis* Jeps.		S	G
Lamiaceae	*Pogogyne serpylloides* (Torr.) A.Gray		V	G
Lamiaceae	*Prunella vulgaris* L. var. *lanceolata* (W.Bartram) Fernald		WV	G
Lamiaceae	*Pycnanthemum californicum* Torr.		V	G
Lamiaceae	*Salvia sonomensis* Greene	N	WVNSR	G
Lamiaceae	*Satureja douglasii* (Benth.) Briq.		R	G
Lamiaceae	*Scutellaria californica* A.Gray	N	WV	G
Lamiaceae	*Scutellaria siphocampyloides* Vatke		N	—
Lamiaceae	*Scutellaria tuberosa* Benth.	N	WVN	G
Lamiaceae	*Stachys stricta* Greene		VN	G
Lamiaceae	*Trichostema lanceolatum* Benth.		VN	G
Lauraceae	*Umbellularia californica* (Hook. & Arn.) Nutt.	N	WVS	G
Liliaceae	*Allium hyalinum* Curran		N	—
Liliaceae	*Allium peninsulare* Lemmon ex Greene	N	WVSR	G
Liliaceae	*Allium sanbornii* Alph.Wood		V	G
Liliaceae	*Allium serra* McNeal & Ownbey		N	—
Liliaceae	*Bloomeria crocea* (Torr.) Coville		N	—
Liliaceae	*Brodiaea elegans* Hoover	N	WVN	G
Liliaceae	*Brodiaea purdyi* Eastw.		V	G
Liliaceae	*Calochortus albus* Douglas ex Benth.	N	WVNSR	G
Liliaceae	*Calochortus luteus* Douglas ex Lindl.		VNR	G
Liliaceae	*Calochortus monophyllus* (Lindl.) Lem.	N	WVR	G

APPENDIX 1. CONTINUED.

Family	Taxon	Native or introduced	Source	Rock
Liliaceae	*Calochortus superbus* Purdy ex J.T.Howell		WV	G
Liliaceae	*Calochortus venustus* Douglas ex Benth.		N	—
Liliaceae	*Chlorogalum angustifolium* Kellogg		N	—
Liliaceae	*Chlorogalum grandiflorum* Hoover	N	WV	G
Liliaceae	*Chlorogalum pomeridianum* (DC.) Kunth	N	WVNSR	G
Liliaceae	*Dichelostemma capitatum* Alph. Wood	N	WVNSR	G
Liliaceae	*Dichelostemma congestum* (Sm.) Kunth	N	WVR	G
Liliaceae	*Dichelostemma multiflorum* (Benth.) A.Heller	N	WVNR	G
Liliaceae	*Dichelostemma volubile* (Kellogg) A.Heller	N	WVNSR	G
Liliaceae	*Erythronium multiscapoideum* (Kellogg) A.Nelson & P.B.Kenn.	N	WVN	G
Liliaceae	*Fritillaria micrantha* A.Heller	N	WVNSR	G
Liliaceae	*Lilium humboldtii* Roezl & Leichtlin ex Duch.		V	G
Liliaceae	*Lilium pardalinum* Kellogg		WVS	G
Liliaceae	*Odontostomum hartwegii* Torr.	N	WN	NG
Liliaceae	*Trillium chloropetalum* (Torr.) Howell	N	W	NG
Liliaceae	*Triteleia bridgesii* (S.Watson) Greene		V	G
Liliaceae	*Triteleia hyacinthina* (Lindl.) Greene	N	WVNR	G
Liliaceae	*Triteleia ixioides* (S.Watson) Greene	N	WVNR	G
Liliaceae	*Triteleia ixioides* (S.Watson) Greene ssp. *scabra* Greene		V	G
Liliaceae	*Triteleia laxa* Benth.	N	WVNR	G
Liliaceae	*Zigadenus venenosus* S.Watson	N	WVN	G
Limnanthaceae	*Limnanthes alba* Benth.	N	WN	G
Limnanthaceae	*Limnanthes douglasii* R.Br. var. *rosea* (Hartw. ex Benth.) C.T.Mason		V	G
Limnanthaceae	*Limnanthes striata* Jeps.		VN	NG
Linaceae	*Hesperolinon micranthum* (A.Gray) Small	N	WVR	G
Linaceae	*Linum bienne* Mill.		V	G
Linaceae	*Linum usitatissimum* L.	I	WV	G
Loasaceae	*Mentzelia laevicaulis* (Douglas ex Hook.) Torr. & A.Gray		N	—
Lythraceae	*Lythrum hyssopifolia* L.		VN	G
Lythraceae	*Rotala ramosior* (L.) Koehne		V	NG
Malvaceae	*Sidalcea calycosa* M.E.Jones		V	G
Malvaceae	*Sidalcea hartwegii* A.Gray	N	WVN	G
Malvaceae	*Sidalcea malvaeflora* (Sesse & Mocino ex DC.) A.Gray ex Benth. ssp. *asprella* (Greene) C.L.Hitchc.	N	WV	G
Marsileaceae	*Marsilea vestita* Hook. & Grev.		V	NG
Oleaceae	*Fraxinus dipetala* Hook. & Arn.		V	G
Oleaceae	*Fraxinus latifolia* Benth.	N	WVNS	G
Onagraceae	*Camissonia micrantha* (Hornem. ex Spreng.) P.H.Raven	N	WV	G
Onagraceae	*Clarkia biloba* (Durand.) A.Nelson & J.F.Macbr.	N	WVN	G
Onagraceae	*Clarkia gracilis* (Piper) A.Nelson & J.F.Macbr.		V	G
Onagraceae	*Clarkia purpurea* (Curtis) A.Nelson & J.F.Macbr.	N	V	G
Onagraceae	*Clarkia purpurea* (Curtis) A.Nelson & J.F.Macbr.ssp. *quadrivulnera* (Douglas ex Lindl.) F.H. Lewis & M.E. Lewis		WVN	G
Onagraceae	*Clarkia rhomboidea* Douglas ex Hook.		VN	G
Onagraceae	*Clarkia unguiculata* Lindl.		NR	G
Onagraceae	*Epilobium brachycarpum* C.Presl	N	WVNS	G
Onagraceae	*Epilobium canum* (Greene) P.H.Raven ssp. *latifolia* (Hook.) P.H.Raven		VNS	G
Onagraceae	*Epilobium ciliatum* Raf.		WV	G
Onagraceae	*Epilobium cleistogama* (Curran) P.Hoch & P.H.Raven	N	W	G
Onagraceae	*Epilobium densiflorum* (Lindl.) Hoch. & P.H.Raven		V	G
Onagraceae	*Epilobium minutum* Lindl. ex Lehm.	N	WVS	G
Onagraceae	*Epilobium torreyi* (S.Watson) Hoch. & P.H.Raven		V	G
Onagraceae	*Ludwigia peploides* (Kunth) P.H.Raven		N	—
Orchidaceae	*Epipactis gigantea* Douglas ex Hook.		WV	G
Orchidaceae	*Piperia elegans* (Lindl.) Rydb.	N	WV	G
Orchidaceae	*Piperia unalascensis* (Spreng.) Rydb.		SR	G
Orchidaceae	*Spiranthes porrifolia* Lindl.		V	NG

Appendix 1. Continued.

Family	Taxon	Native or introduced	Source	Rock
Orobanchaceae	*Orobanche bulbosa* (A.Gray) G.Beck	N	WVR	G
Orobanchaceae	*Orobanche fasciculata* Nutt.		R	G
Orobanchaceae	*Orobanche uniflora* L.	N	WR	G
Orobanchaceae	*Orobanche uniflora* L. var. *sedii* (Suksd.) Achey		V	NG
Papaveraceae	*Eschscholzia caespitosa* Benth.	N	WVNS	G
Papaveraceae	*Eschscholzia californica* Cham.		VNR	G
Papaveraceae	*Eschscholzia lobbii* Greene	N	WVN	G
Papaveraceae	*Meconella californica* Torr.		VN	G
Papaveraceae	*Platystemon californicus* Benth.		WVN	NG
Pinaceae	*Pinus ponderosa* C.Lawson	N	WVNSR	G
Pinaceae	*Pinus sabiniana* Douglas ex Douglas	N	WVNSR	G
Pinaceae	*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*		WNS	G
Plantaginaceae	*Plantago erecta* Morris	N	WVNSR	G
Plantaginaceae	*Plantago lanceolata* L.		WVNSR	G
Plantaginaceae	*Plantago major* L.		VN	G
Poaceae	*Achnatherum lemmonii* (Vasey) Barkworth	N	WVSR	G
Poaceae	*Aegilops triuncialis* L.	I	WVR	G
Poaceae	*Agrostis exarata* Trin.		V	G
Poaceae	*Aira caryophyllea* L.	I	WVSR	G
Poaceae	*Andropogon virginicus* L.		S	G
Poaceae	*Avena barbata* Pott ex Link	I	WVSR	G
Poaceae	*Avena fatua* L.	I	WVR	G
Poaceae	*Brachypodium distachyon* (L.) P.Beauv.	I	WVSR	G
Poaceae	*Briza minor* L.	I	WVSR	G
Poaceae	*Bromus arenarius* Labill.		S	NG
Poaceae	*Bromus carinatus* Hook. & Arn.	N	WVR	G
Poaceae	*Bromus diandrus* Roth	I	WVSR	G
Poaceae	*Bromus hordeaceus* L.	I	WVS	G
Poaceae	*Bromus laevipes* Shear	N	WVSR	G
Poaceae	*Bromus madritensis* L.	I	WVSR	G
Poaceae	*Bromus madritensis* L. ssp. *rubens* (L.) Duvin	I	WVSR	G
Poaceae	*Bromus sterilis* L.	I	WVR	G
Poaceae	*Bromus tectorum* L.		V	G
Poaceae	*Crypsis schoenoides* (L.) Lam.		S	G
Poaceae	*Cynodon dactylon* (L.) Pers.		S	G
Poaceae	*Cynosurus echinatus* L.	I	WVSR	G
Poaceae	*Danthonia californica* Boland var. *americana* (Scribn.) Hitchc.		R	G
Poaceae	*Danthonia unispicata* (Thurb.) Munro ex Macoun	N	WV	G
Poaceae	*Deschampsia danthonioides* (Trin.) Munro		R	G
Poaceae	*Digitaria sanguinalis* (L.) Scop.		V	G
Poaceae	*Echinochloa crusgalli* (L.) P.Beauv.		V	G
Poaceae	*Elymus elymoides* (Raf.) Swezey		V	G
Poaceae	*Elymus glaucus* Buckley ssp. *jepsonii* Burtt Davy	N	V	G
Poaceae	*Elymus multisetus* (J.G.Sm.) Burtt Davy	N	WVSR	G
Poaceae	*Eragrostis hypnoides* (Lam.) Britton, Sterns & Poggenb.		V	NG
Poaceae	*Gastridium ventricosum* (Gouan) Schinz & Thell.	I	W	G
Poaceae	*Holcus lanatus* L.		S	G
Poaceae	*Hordeum depressum* (Scribn. & J.G.Sm.) Rydb.	N	WV	G
Poaceae	*Hordeum marinum* Huds. ssp. *gussoneanum* (Parl.) Thell.	I	WVR	G
Poaceae	*Hordeum murinum* L. ssp. *leporinum* (Link) Arcang.	I	WVR	NG
Poaceae	*Hordeum vulgare* L.		W	G
Poaceae	*Koeleria macrantha* (Ledeb.) Schult.		R	G
Poaceae	*Leersia oryzoides* (L.) Sw.		VS	G
Poaceae	*Lolium multiflorum* Lam.	I	WV	G
Poaceae	*Lolium perenne* L.	I	WV	G
Poaceae	*Lolium temulentum* L.	I	W	G
Poaceae	*Melica californica* Scribn.	N	WVSR	G
Poaceae	*Melica torreyana* Scribn.	N	WVSR	G
Poaceae	*Muhlenbergia rigens* (Benth.) Hitchc.		VS	G
Poaceae	*Nassella cernua* (Stebbins & R.M.Love) Barkworth	N	WVSR	G

APPENDIX 1. CONTINUED.

Family	Taxon	Native or introduced	Source	Rock
Poaceae	*Nassella pulchra* (Hitchc.) Barkworth	N	WVR	G
Poaceae	*Panicum acuminatum* Sw. var. *acuminatum*		S	G
Poaceae	*Panicum capillare* L.		V	G
Poaceae	*Phalaris aquatica* L.	I	WVR	G
Poaceae	*Phalaris lemmonii* Vasey	N	W	G
Poaceae	*Phalaris minor* Retz.		V	G
Poaceae	*Piptatherum miliaceum* (L.) Coss.	I	WV	G
Poaceae	*Poa annua* L.	I	WVSR	G
Poaceae	*Poa bulbosa* L.	I	WVR	G
Poaceae	*Poa compressa* L.		V	G
Poaceae	*Poa pratensis* L.		WS	G
Poaceae	*Poa secunda* J.Presl ssp. *secunda*	N	WVS	G
Poaceae	*Poa tenerrima* Scribn.		V	G
Poaceae	*Polypogon maritimus* Willd.	I	WV	G
Poaceae	*Polypogon monspeliensis* (L.) Desf.		W	—
Poaceae	*Scribneria bolanderi* (Thurb.) Hack.		V	G
Poaceae	*Setaria pumila* (Poir.) Roem. & Schult.		V	G
Poaceae	*Sorghum halepense* (L.) Pers.		WV	G
Poaceae	*Taeniatherum caput-medusae* (L.) Nevski	I	WV	G
Poaceae	*Vulpia bromoides* (L.) Gray		S	G
Poaceae	*Vulpia microstachys* (Nutt.) Munro var. *ciliata* (Beal) Lonard & Gould	N	WR	G
Poaceae	*Vulpia microstachys* (Nutt.) Munro var. *confusa* (Piper) Lonard & Gould	N	WV	
Poaceae	*Vulpia microstachys* (Nutt.) Munro var. *pauciflora* (Scribn. ex Beal) Lonard & Gould	N	WV	G
Poaceae	*Vulpia myuros* (L.) C.C.Gmel.	I	WV	G
Poaceae	*Vulpia myuros* (L.) C.C.Gmel. var. *hirsuta* Hack.	I	WVSR	G
Poaceae	*Vulpia octoflora* (Walter) Rydb. var. *hirtella* (Piper) Henr.	N	WV	G
Polemoniaceae	*Allophyllum divaricatum* (Nutt.) A.D.Grant & V.E.Grant		V	G
Polemoniaceae	*Allophyllum gilioides* (Benth.) A.D.Grant & V.E.Grant		V	G
Polemoniaceae	*Collomia heterophylla* Hook.		S	G
Polemoniaceae	*Gilia capitata* Sims	N	WS	G
Polemoniaceae	*Gilia capitata* Sims ssp. *pedemontana* V.E.Grant		VNR	G
Polemoniaceae	*Gilia tricolor* Benth.	N	WN	NG
Polemoniaceae	*Gilia tricolor* Benth. ssp. *diffusa* (Congd.) H.Mason & A.D.Grant		V	NG
Polemoniaceae	*Linanthus androsaceus* (Benth.) Greene		N	—
Polemoniaceae	*Linanthus bicolor* (Nutt.) Greene	N	WVNR	G
Polemoniaceae	*Linanthus ciliatus* (Benth.) Greene	N	WR	G
Polemoniaceae	*Linanthus dichotomus* Benth.		N	—
Polemoniaceae	*Linanthus filipes* (Benth.) Greene	N	W	NG
Polemoniaceae	*Linanthus montanus* (Greene) Greene		V	G
Polemoniaceae	*Linanthus parviflorus* (Benth.) Greene		V	G
Polemoniaceae	*Linanthus pygmaeus* (Brand) J.T.Howell	N	WV	G
Polemoniaceae	*Navarretia eriocephala* H.Mason		V	G
Polemoniaceae	*Navarretia filicaulis* (Torr. ex A.Gray) Greene	N	WV	G
Polemoniaceae	*Navarretia intertexta* (Benth.) Hook.	N	WVN	G
Polemoniaceae	*Navarretia pubescens* (Benth.) Hook. & Arn.	N	WVN	G
Polemoniaceae	*Navarretia viscidula* Benth.		V	G
Polemoniaceae	*Navarretia viscidula* Benth. ssp. *purpurea* (Greene) H.Mason		R	G
Polemoniaceae	*Phlox gracilis* Greene		WV	G
Polygalaceae	*Polygala cornuta* Kellogg	N	WVSR	G
Polygonaceae	*Chorizanthe membranacea* Benth.		V	G
Polygonaceae	*Chorizanthe polygonoides* Torr. & A.Gray		WV	G
Polygonaceae	*Chorizanthe staticoides* Benth.	N	V	G
Polygonaceae	*Eriogonum nudum* Douglas ex Benth.	N	WV	NG
Polygonaceae	*Eriogonum umbellatum* Torr.		N	—
Polygonaceae	*Eriogonum vimineum* Douglas ex Benth.		V	G
Polygonaceae	*Polygonum arenastrum* Jord. ex Boreau		V	G

APPENDIX 1. CONTINUED.

Family	Taxon	Native or introduced	Source	Rock
Polygonaceae	*Polygonum californicum* Meisn.	N	WV	G
Polygonaceae	*Polygonum convolvulus* L.		N	—
Polygonaceae	*Polygonum punctatum* Elliot		V	G
Polygonaceae	*Pterostegia drymarioides* Fisch. & C.A.Mey.		VS	G
Polygonaceae	*Rumex acetocella* L.		V	G
Polygonaceae	*Rumex conglomeratus* Murray		VN	G
Polygonaceae	*Rumex crispus* L.	I	WVNS	G
Polygonaceae	*Rumex obtusifolius* L.		S	G
Polygonaceae	*Rumex pulcher* L.	I	WV	G
Polygonaceae	*Rumex salicifolius* Weinm. var. *denticulatus* Torr.	N	WV	G
Polypodiaceae	*Polypodium californicum* Kaulf.	N	WVNSR	G
Portulacaceae	*Calandrinia ciliata* (Ruiz & Pav.) DC. var. *menziesii* (Hook.) J.F.Macbr.	N	WVNSR	G
Portulacaceae	*Claytonia exigua* Torr. & A.Gray		V	G
Portulacaceae	*Claytonia parviflora* Douglas ex Hook.		WVR	G
Portulacaceae	*Claytonia perfoliata* Donn ex Willd.	N	VNSR	G
Portulacaceae	*Montia fontana* L.		V	G
Portulacaceae	*Portulaca oleracea* L.		N	—
Primulaceae	*Anagallis arvensis* L.	I	WVNS	G
Primulaceae	*Centunculus minimus* L.		V	NG
Primulaceae	*Dodecatheon hendersonii* A.Gray	N	WVNSR	G
Primulaceae	*Trientalis latifolia* Hook.	N	W	NG
Pteridaceae	*Adiantum jordanii* C.H.Mull.	N	WVNS	G
Pteridaceae	*Aspidotis californica* (Hook.) Nutt. ex Copel.	N	WSR	G
Pteridaceae	*Cheilanthes intertexta* (Maxon) Maxon		VR	G
Pteridaceae	*Pellaea andromedaefolia* (Kaulf.) Fée		VS	G
Pteridaceae	*Pellaea mucronata* (D.C.Eaton) D.C.Eaton	N	WVNSR	G
Pteridaceae	*Pentagramma pallida* (Weath.) Yatsk., Windham & E.Wollenw.		V	G
Pteridaceae	*Pentagramma triangularis* (Kaulf.) Maxon	N	WVNSR	G
Pteridaceae	*Pteridium aquilinum* (L.) Kuhn var. *pubescens* Underw.		WVN	G
Ranunculaceae	*Aquilegia formosa* Fisch. ex DC.		WV	G
Ranunculaceae	*Clematis lasiantha* Nutt.	N	WVNSR	G
Ranunculaceae	*Delphinium gracilentum* Greene		S	G
Ranunculaceae	*Delphinium hansenii* (Greene) Greene		VSN	G
Ranunculaceae	*Delphinium hesperium* A.Gray		WV	G
Ranunculaceae	*Delphinium patens* Benth.	N	WVN	G
Ranunculaceae	*Isopyrum occidentale* Hook. & Arn.	N	W	NG
Ranunculaceae	*Ranunculus aquatilis* L. var. *hispidulus* E.Drew		W	NG
Ranunculaceae	*Ranunculus arvensis* L.		V	G
Ranunculaceae	*Ranunculus californicus* Benth.		V	G
Ranunculaceae	*Ranunculus hebecarpus* Hook. & Arn.	N	WVS	G
Ranunculaceae	*Ranunculus hystriculus* A.Gray		N	—
Ranunculaceae	*Ranunculus muricatus* L.		WVS	G
Ranunculaceae	*Ranunculus occidentalis* Nutt. var. *eisenii* (Kellogg) A.Gray	N	WVNR	G
Ranunculaceae	*Thalictrum fendleri* Engelm. ex A.Gray var. *polycarpum* Torr.		WN	NG
Rhamnaceae	*Ceanothus cuneatus* (Hook.) Nutt.	N	WVN	G
Rhamnaceae	*Ceanothus integerrimus* Hook. & Arn.	N	WVN	G
Rhamnaceae	*Ceanothus lemmonii* Parry	N	WVNSR	G
Rhamnaceae	*Ceanothus leucodermis* Greene		N	—
Rhamnaceae	*Ceanothus palmeri* Trel.	N	WV	NG
Rhamnaceae	*Ceanothus roderickii* Knight	N	WVR	G
Rhamnaceae	*Rhamnus californica* Eschsch.	N	N	—
Rhamnaceae	*Rhamnus ilicifolia* Kellogg	N	WVSR	G
Rhamnaceae	*Rhamnus tomentella* Benth. ssp. *crassifolia* (Jeps.) J.O.Sawyer		WVSR	G
Rosaceae	*Adenostoma fasciculatum* Hook. & Arn.	N	WVNSR	G
Rosaceae	*Amelanchier utahensis* Koehne		W	—
Rosaceae	*Aphanes occidentalis* (Nutt.) Rydb.	N	WVS	G
Rosaceae	*Cercocarpus betuloides* Nutt.	N	WVNS	G
Rosaceae	*Chamaebatia foliolosa* Benth.		N	—

APPENDIX 1. CONTINUED.

Family	Taxon	Native or introduced	Source	Rock
Rosaceae	*Fragaria vesca* L. ssp. *californica* (Cham. & Schltdl.) Staudt		N	—
Rosaceae	*Heteromeles arbutifolia* (Lindl.) Roem.	N	WVNSR	G
Rosaceae	*Horkelia californica* Cham. & Schltdl. ssp. *dissita* (Crum) Ertter		V	G
Rosaceae	*Horkelia fusca* Lindl. ssp. *parviflora* (Nutt. ex Torr. & A.Gray) D.D.Keck		V	G
Rosaceae	*Malus sylvestris* Mill.		N	—
Rosaceae	*Oemleria cerasiformis* (Hook. & Arn.) J.W.Landon	N	W	NG
Rosaceae	*Potentilla glandulosa* Lindl.	N	WN	G
Rosaceae	*Potentilla glandulosa* Lindl. ssp. *reflexa* (Greene) D.D.Keck		VS	G
Rosaceae	*Prunus ilicifolia* (Nutt. ex Hook. & Arn.) D.Dietr.		N	—
Rosaceae	*Rosa californica* Cham. & Schltdl.	N	W	NG
Rosaceae	*Rosa eglanteria* L.		V	G
Rosaceae	*Rubus armeniacus* Focke		WVS	G
Rosaceae	*Rubus leucodermis* Douglas ex Torr. & A.Gray	N	WN	G
Rosaceae	*Rubus ursinus* Cham. & Schltdl.	N	WV NS	G
Rosaceae	*Sanguisorba minor* Scop. ssp. *muricata* (Spach ex Bonnier & Layens) Nordborg		NV	G
Rubiaceae	*Cephalanthus occidentalis* L. var. *californicus* Benth.		VNS	G
Rubiaceae	*Galium aparine* L.	N	WVNSR	G
Rubiaceae	*Galium bolanderi* A.Gray	N	WVSR	G
Rubiaceae	*Galium californicum* Hook. & Arn. ssp. *sierrae* Dempster & Stebbins	N	WVR	G
Rubiaceae	*Galium divaricatum* Lam.	I	WV	G
Rubiaceae	*Galium murale* (L.) All.		V	NG
Rubiaceae	*Galium parisiense* L.	I	WVNS	G
Rubiaceae	*Galium porrigens* Dempster	N	WVSR	G
Rubiaceae	*Sherardia arvensis* L.	I	WV	G
Rutaceae	*Ptelea crenulata* Greene	N	WVS	G
Salicaceae	*Populus fremontii* S.Watson		WVS	G
Salicaceae	*Salix exigua* Nutt.		WVN	G
Salicaceae	*Salix gooddingii* C.R.Ball	N	WVN	G
Salicaceae	*Salix laevigata* Bebb		S	G
Salicaceae	*Salix lasiolepis* Benth.		WVN	G
Salicaceae	*Salix lucida* Muhl. ssp. *lasiandra* (Benth.) E.Murray		V	G
Salicaceae	*Salix melanopsis* Nutt.		VN	G
Santalaceae	*Comandra umbellata* (L.) Nutt. ssp. *californica* (Eastw. ex Rydb.) M.Piehl		VS	G
Saxifragaceae	*Boykenia occidentalis* Torr. & A.Gray		WVN	G
Saxifragaceae	*Darmera peltata* (Torr. ex Benth.) Voss		V	G
Saxifragaceae	*Lithophragma affine* A.Gray		VN	NG
Saxifragaceae	*Lithophragma bolanderi* A.Gray		VS	G
Saxifragaceae	*Lithophragma heterophyllum* (Hook. & Arn.) Torr. & A.Gray	N	VN	G
Saxifragaceae	*Lithophragma parviflorum* (Hook.) Torr. & A.Gray		V	G
Saxifragaceae	*Philadelphus lewisii* Pursh ssp. *californica* (Benth.) Munz	N	WVNS	G
Saxifragaceae	*Saxifraga californica* Greene	N	WVNS	G
Scrophulariaceae	*Antirrhinum cornutum* Benth.	N	WV	G
Scrophulariaceae	*Antirrhinum vexillocalyculatum* Kellogg ssp. *breweri* (A.Gray) D.Thomp.		V	NG
Scrophulariaceae	*Castilleja applegatei* Fernald		V	G
Scrophulariaceae	*Castilleja attenuata* (A.Gray) T.I.Chuang & Heckard	N	WVSR	G
Scrophulariaceae	*Castilleja exerta* (A.Heller) T.I.Chuang & Heckard		VR	G
Scrophulariaceae	*Castilleja foliolosa* Hook. & Arn.	N	WVNSR	G
Scrophulariaceae	*Castilleja lacera* (Benth.) T.I.Chuang & Heckard		V	G
Scrophulariaceae	*Castilleja lineariloba* (Benth.) T.I.Chuang & Heckard		WV	G
Scrophulariaceae	*Castilleja rubicundula* (Jeps.) T.I.Chuang & Heckard ssp. *lithospermoides* (Benth.) T.I.Chuang & Heckard	N	WVN	G
Scrophulariaceae	*Castilleja subinclusa* Greene		VN	G
Scrophulariaceae	*Collinsia heterophylla* Buist ex Graham		WVNSR	G

Appendix 1. Continued.

Family	Taxon	Native or introduced	Source	Rock
Scrophulariaceae	*Collinsia sparsiflora* Fisch. & C.A.Mey. var. *bruceae* (M.E.Jones) Newsom	N	WVN V	G
Scrophulariaceae	*Collinsia sparsiflora* Fisch. & C.A.Mey. var. *collina* (Jeps.) Newsom		WVN	G
Scrophulariaceae	*Collinsia tinctoria* Hartw. ex Benth.		N	—
Scrophulariaceae	*Cordylanthus pilosus* A.Gray ssp. *hansenii* (Ferris) T.I.Chuang & Heckard		VN	G
Scrophulariaceae	*Grateola ebracteata* Benth.		V	NG
Scrophulariaceae	*Keckiella breviflora* (Lindl.) Straw	N	WVNSR	G
Scrophulariaceae	*Keckiella lemmonii* (A.Gray) Straw		R	G
Scrophulariaceae	*Kickxia elatine* (L.) Dumort.		V	G
Scrophulariaceae	*Linaria canadensis* (L.) Dum.Cours. var. *texana* (Scheele) Pennell		W	G
Scrophulariaceae	*Lindernia dubia* (L.) Pennell var. *anagallidea* (Michx.) Cooperr.		V	G
Scrophulariaceae	*Mimulus aurantiacus* W.Curtis	N	WVNSR	G
Scrophulariaceae	*Mimulus cardinalis* Benth.		WVNS	G
Scrophulariaceae	*Mimulus douglasii* (Douglas ex Benth.) A.Gray		V	G
Scrophulariaceae	*Mimulus guttatus* DC.		WNS	G
Scrophulariaceae	*Mimulus kelloggii* (Curran ex Greene) Curran ex A.Gray		VNS	G
Scrophulariaceae	*Mimulus layneae* (Greene) Jeps.		V	G
Scrophulariaceae	*Mimulus pilosus* (Benth.) S.Watson		V	G
Scrophulariaceae	*Mimulus tricolor* Hartw. ex Lindl.		VN	G
Scrophulariaceae	*Pedicularis densiflora* Benth. ex Hook.		N	—
Scrophulariaceae	*Penstemon azurens* Benth.	N	WV	G
Scrophulariaceae	*Penstemon heterophyllus* Lindl.		WVNS	G
Scrophulariaceae	*Scrophularia californica* Cham. & Schltdl.	N	NS	G
Scrophulariaceae	*Scrophularia californica* Cham. & Schltdl. ssp. *floribunda* (Greene) R.J.Shaw		WV	G
Scrophulariaceae	*Triphysaria eriantha* (Benth.) T.I.Chuang & Heckard	N	WVNS	G
Scrophulariaceae	*Triphysaria pusilla* (Benth.) T.I.Chuang & Heckard		V	G
Scrophulariaceae	*Verbascum blattaria* L.	I	WVN	G
Scrophulariaceae	*Verbascum thapsus* L.		WVNS	G
Scrophulariaceae	*Veronica arvensis* L.	I	W	G
Scrophulariaceae	*Veronica peregrina* L. ssp. *xalapensis* (Kunth) Pennell		V	NG
Scrophulariaceae	*Veronica persica* Poir.		V	NG
Selaginellaceae	*Selaginella douglasii* (Hook. & Grev.) Spring		V	G
Selaginellaceae	*Selaginella hanseni* Hieron.	N	WS	G
Selaginellaceae	*Selaginella wallacei* Hieron.		S	G
Simarubaceae	*Ailanthus altissima* (Mill.) Swingle		N	—
Solanaceae	*Datura stramonium* L. var. *tatula* (L.) Torr.		VN	G
Solanaceae	*Datura wrightii* Regel		N	—
Solanaceae	*Nicotiana acuminata* (Graham) Hook. var. *multiflora* (Phil.) Reiche		WVN	G
Solanaceae	*Nicotiana attenuata* Torr. ex S.Watson		N	—
Solanaceae	*Nicotiana glauca* Graham		N	—
Solanaceae	*Nicotiana quadrivalvis* Pursh		N	—
Solanaceae	*Solanum americanum* Mill.		WV	G
Solanaceae	*Solanum xantii* A.Gray		WVN	G
Sterculiaceae	*Fremontodendron californicum* (Torr.) Coville ssp. *decumbens* (R. Lloyd) Munz	N	WVR	G
Styracaceae	*Styrax officinalis* L. var. *redivivus* (Torr.) Howard	N	WVNS	G
Tamaricaceae	*Tamarix parviflora* DC.		V	G
Typhaceae	*Typha domingensis* Pers.		NS	NG
Typhaceae	*Typha latifolia* L.		WVN	G
Urticaceae	*Urtica dioica* L. ssp. *holosericea* (Nutt.) Thorne		VN	G
Valerianaceae	*Plectritis ciliosa* (Greene) Jeps.	N	WVNS	G
Valerianaceae	*Plectritis macrocera* Torr. & A.Gray		NR	G
Valerianaceae	*Valerianella locusta* (L.) Laterr.		V	G
Verbenaceae	*Phyla nodiflora* (L.) Greene var. *nodiflora*		VNS	G
Verbenaceae	*Verbena bonariensis* (A.DC.) A.Gray		V	G
Verbenaceae	*Verbena hastata* L.		N	—

Appendix 1. Continued.

Family	Taxon	Native or introduced	Source	Rock
Verbenaceae	*Verbena litoralis* Kunth		S	G
Violaceae	*Viola douglasii* Steud.		N	—
Viscaceae	*Arceuthobium campylopodum* Engelm.		WVN	G
Viscaceae	*Phoradendron macrophyllum* (Engelm.) Cockerell		VN	G
Vitaceae	*Vitis californica* Benth.	N	WVNS	G